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ENGINEERS' DIGEST

REVIEW OF ENGINEERING PROGRESS ABROAD

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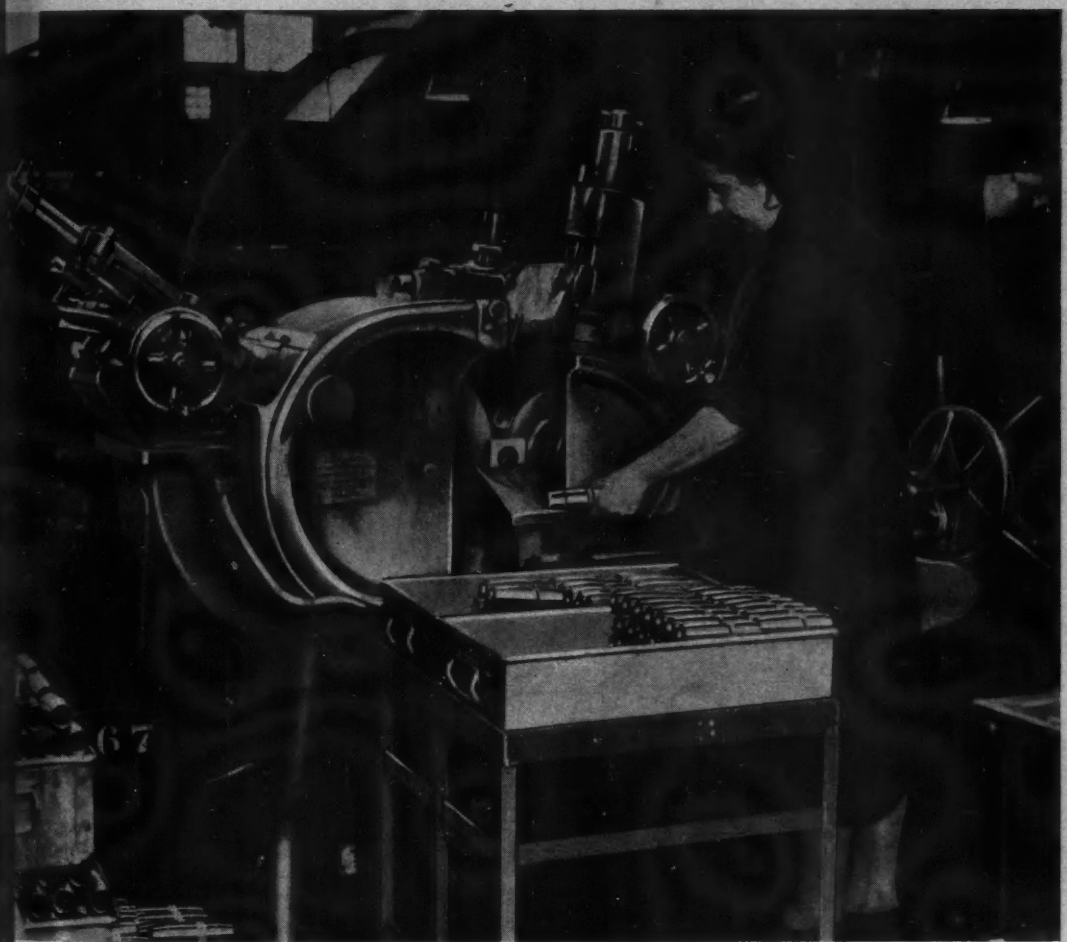

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CONTENTS

	page
The Aerodynamic Turbine versus Steam and Gas Turbines *"The Engineers' Digest," Vol. 5, No. 3, p. 77.*	77
Blow-Hole Formation in Oxy-Acetylene Welding of Aluminium Alloy Al-Mg. 7 *"The Engineers' Digest," Vol. 5, No. 3, p. 71.*	71
Cast Iron as Construction Material *"The Engineers' Digest," Vol. 5, No. 3, p. 61.*	61
Distillation of Mixtures of Coal-Mud and Coal *"The Engineers' Digest," Vol. 5, No. 3, p. 64.*	64
A Graphite-Rod Resistance Type Melting Furnace *"The Engineers' Digest," Vol. 5, No. 3, p. 85.*	85
Importance of Proper Choice of Heat Exchanger Surface, particularly in Power Plant Equipment *"The Engineers' Digest," Vol. 5, No. 3, p. 83.*	83
A New Hydrodynamic Principle of Sound Measurement *"The Engineers' Digest," Vol. 5, No. 3, p. 70.*	70
Operating Economy of Pneumatic and Steam Forging Hammers *"The Engineers' Digest," Vol. 5, No. 3, p. 75.*	75
Recent Developments of the Escher-Wyss Steam Turbine *"The Engineers' Digest," Vol. 5, No. 3, p. 78.*	78
Relationship between Salt Content and Conductivity of Boiler Water in Electric Boiler Operation *"The Engineers' Digest," Vol. 5, No. 3, p. 86.*	86
"Soft Skin" on Highly Finished Surfaces *"The Engineers' Digest," Vol. 5, No. 3, p. 65.*	65
The Soviet W2 Tank Diesel *"The Engineers' Digest," Vol. 5, No. 3, p. 67.*	67
Starting of Large Engines *"The Engineers' Digest," Vol. 5, No. 3, p. 69.*	69
Temperature Distribution in Lathe Cutting Tools *"The Engineers' Digest," Vol. 5, No. 3, p. 71.*	71

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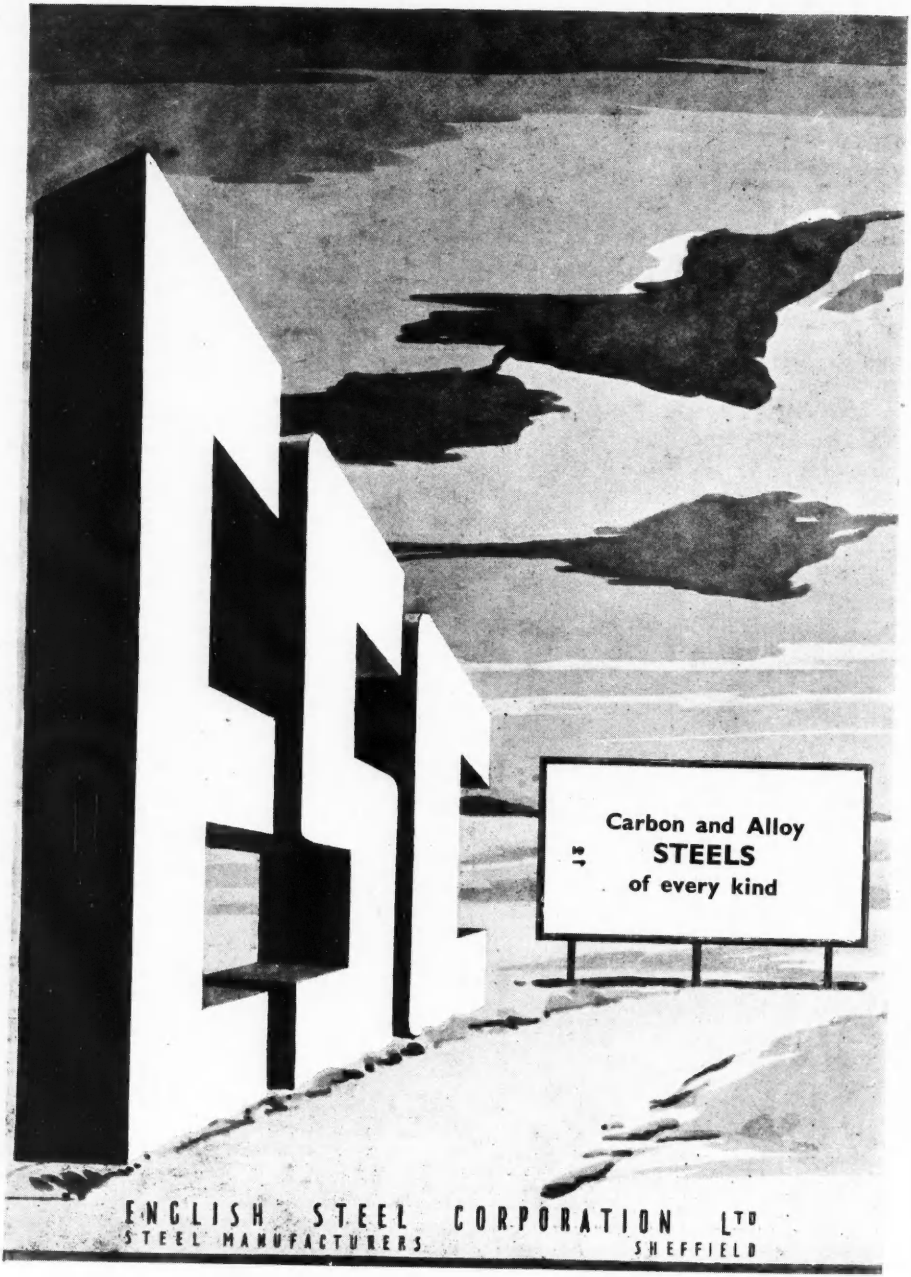
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CAST IRON AS CONSTRUCTION MATERIAL.

By E. PIWOWARSKY. (From *Die Giesserei*, Vol. 30, No.12/13, June, 1943, pp. 141-152).

MUCH of the decline in the employment of cast iron as construction material, which began some sixty years ago, had been the logical consequence of the development of the classical theory of the strength of materials based upon their elastic properties. Modern times have, however, witnessed a partial abandonment of former conceptions of strength and the gradual development of a new theory of design. It is this trend which, combined with considerable improvements in the strength properties of cast iron, has given a new impetus to the employment of this material.

Earlier conceptions of strength were based upon an unimpeded establishment of lines of stress and upon the elastic behaviour of the material thus stressed. The results of static tensile tests were taken as a criterion of toughness, to be supplemented in certain cases by impact tests conducted either with plain or notched bars. Cases in which the original theory proved at fault became more and more numerous, and at least nine out of ten fractures could be adjudged as having been caused by fatigue. On the other hand, many cast iron pieces failed to give way to fatigue, the cast iron crankshaft proving an outstanding example in this respect. This led to a gradual recognition of the importance of "contour" upon true strength, and of such factors as damping, surface condition, local stress concentration, and others; the influence of combined stresses, such as joint torsion and bending, also received more attention. The factor of static strain greatly lost its importance, once it was recognized to be mainly an indicator of the degree of deformation preceding failure by excessive loading. As R. Bertschinger (1) correctly states, even in cases of failure by overstress it would often have been better to use a less ductile material in order to prevent a complete destruction of the machine in question. Thus, elongation has to-day lost much of its earlier importance in assessing the properties of a material, and only remains as an "indicator of certain properties which are desirable but still insufficiently known."

It has, moreover, been found that a material of greater elongation but of small damping can be inferior to one combining a relatively smaller degree of elongation with higher damping characteristics(2). Furthermore, J. G. Pearce has shown that a material of small strength and very small elongation to fracture may exhibit better dynamic characteristics than one combining higher strength with higher elongation(3).

It is therefore possible that materials with small static elongation as, for instance, cast iron, may exhibit good characteristics below the fatigue limit, provided they possess such specific properties as high damping, low notch sensitivity, high resistance at the root of the notch; and these conditions are met by cast iron to a very large extent. Fatigue strength investigations conducted into the notch strength of cast iron have shown that this material of low elongation possesses a more pronounced faculty of stress relief at points of stress concentration than that exhibited by materials elongating according to Hooke's law. Thus, cast iron must be considered to possess a particularly pronounced property of distributing local stress to neighbouring zones. It follows that the value of the static strain test as a measure of the notch sensitivity of materials stressed below the fatigue limit has been greatly overrated. In general, it is recommended that consideration be given to the irreversible phenomena above the fatigue limit (particularly in the range of plastic deformation prior to the occurrence of fracture) as apart from the reversible phenomena occurring below the fatigue limit. This applies in particular to conditions usually encountered in everyday practice.

E. Piwowarsky, R. Bertschinger, and H. Gilgenberg(4) investigated the influence of the carbon content upon both the tensile strength and the bending fatigue limit of grey cast iron. Cast iron of low carbon content is known to tend to a network-like disposition of graphite and with it to a decrease in tensile strength which may be very considerable under certain conditions. This phenomenon is exemplified by the test results obtained by E. Piwowarsky and his co-workers and reproduced in Fig. 1. Here it is seen that the decrease in fatigue strength with increased carbon percentage is considerably less than that for the tensile strength. Extrapolation of the test values leads to a linear relationship of tensile and of fatigue strength, but this relationship need not necessarily be of general validity.

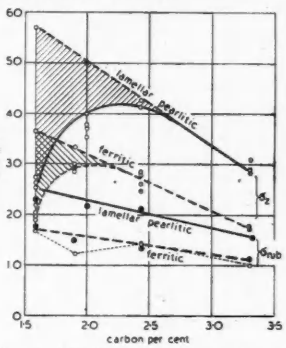


Fig. 1. **Influence of network - like graphite formation upon bending fatigue strength of cast iron.**

Considering the favourable damping properties of cast iron, it would of course be possible to compensate for the less favourable characteristics of other materials in this respect by appropriate design of the part in question, as for instance, the ribbed construction of a welded machine tool bed. But this does not detract from the fact that a material with better damping properties permits a design with better damping characteristics in itself. The contention put forth by some steel experts that steel exhibits an increase in damping properties with increasing stress is quite correct; but the fact remains that good damping characteristics in the low stress range approximating to those encountered in practice constitutes an almost unique property of cast iron. This fact has been pointed out by J. Geiger(5). It has also been shown by A. Thum and his co-workers on repeated occasions that, in spite of their lower tensile strength, cast iron structures may exhibit a fatigue strength which may be either smaller, equally good, or even superior when compared with steel. Furthermore, it is a fact that, in a number of cases where a substitution of cast iron by steel or steel castings had been considered permissible, the use of cast iron was again resorted to.

In the present day trend towards light weight design, cast iron is a particularly suitable material, since it can easily be given the required shape. It possesses a small shrinkage, small tendency to piping, and it is easily machined, in addition to the other favourable properties discussed above. Modern high grade cast iron can therefore be considered competitive even with forged steel.

With regard to weldability certain difficulties are encountered with steels of more than 0.35 per cent carbon content. The tendency of steel to weld-fissures, exhibited with increased carbon content, will remain an unsolved problem for a considerable time to come.

The strength values of welded parts of steel with carbon content below 0.35 per cent are, however, not much higher than those of high grade cast iron.

IS CAST IRON A BRITTLE MATERIAL?

In assessing the phenomenon of brittleness, different considerations must be applied according to whether the stresses involved lie above or below the fatigue limit. Thus, when investigating the influence of phosphorus content upon the impact strength of cast iron, it is found that with a strength of blow leading to fracture after the application of one or two blows, a phosphorus content exceeding 0.1-0.2 per cent caused a decrease in impact strength. According to A. Thum and O. Petri(7), however, with an impact of 6 to 7 cm. kg. per sq. cm. applied to pieces 20 mm. dia., a phosphorus content as high as 1.4 per cent did not influence the impact fatigue strength. (In these tests the fatigue strength was based upon the endurance of 5-6 million blows). When applying the Woehler bending fatigue test to specimens with and without notch, the fatigue strength was found to increase with the phosphorus content, while the adverse influence of the notch became of importance only gradually. E. Piwowarsky(8) has therefore suggested the establishment of the term "dynamic brittleness" or "dynamic toughness" for impact loads below the fatigue limit and to use the term "blow brittleness" or "blow toughness" for destructive blows.

The increased tensile strength obtainable from high grade cast iron is known to be accompanied by an extraordinary increase in impact fatigue strength. The materials tested in Table 1 were recently investigated by E. Piwowarsky and A. Gabriel(9) who ascertained the dynamic properties plotted in Fig. 2. Here it is seen that special cast iron varieties of 42 kg. per sq. mm. tensile strength yielded fatigue strengths superior to those of all other materials considered. Here again it could be shown that with blows of small impact energy, an adverse influence of the phosphorus content could hardly be proven. The type of impact testing machine used for these tests is shown in Fig. 3, where the blows are seen to be applied to the extreme end of the cantilever constituted by the test specimens (measuring 3×5 mm. in cross section). The number of blows applied by the two spring-operated striking pins could be varied from 665 to 1980 per minute. Six machines of this type were used in this test.

For the successful exploitation of these favourable data in actual machine construction, it is of foremost importance that abrupt changes in section should be avoided and that sufficiently large corner radii should be used in smoothing out changes in section. Close adherence to these safeguards has made it possible to produce cast iron crankshafts with a fatigue strength exceeding by 25 per cent that of a comparable crankshaft of forged alloy steel.

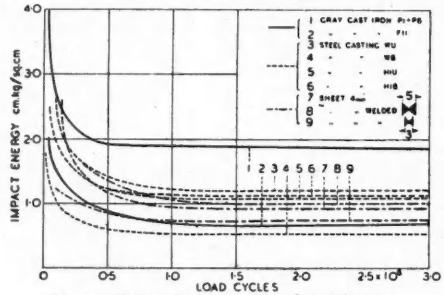
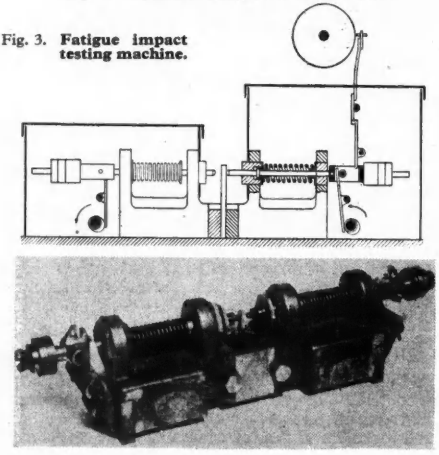


Fig. 2. **Dynamic properties of cast iron.**

Fig. 3. **Fatigue impact testing machine.**



THE ROLLING OF CAST IRON.

Based on actual rolling mill tests conducted on a large scale, Nipper(10) pointed the way to the application of the rolling mill to the rolling of cast iron. Since then, several hundred rolling tests with cast iron of a variety of kinds and compositions have been undertaken. With these a further clarification of the problems connected with the fissure-less rolling of this material has been achieved. The reductions applied in the various passes for a typical rolling process are given in Fig. 4.

Pass	Area of Section sq. mm.	Reduction per cent.		
1	205.0	10	2— 4	29.6%
2	184.5	20	4— 6	15.3%
3	147.6	12	6— 8	29.6%
4	129.9	8	8—10	27.8%
5	119.5	8		
6	110.0	20		
7	88.0	12		
8	77.4	15		
9	65.8	15		
10	55.9	10		
11	50.3			

Fig. 4. **Arrangement of passes for rolling cast iron.**

TABLE I.

Material	Total Carbon %	Si %	Mn %	P %	S %	Tensile Strength kg/mm²	Hardness kg/mm²
Cast iron F 11	3.69	3.12	0.46	0.87	—	30.9	250
Cast iron P 1	3.51	2.73	0.83	0.27	—	42.3	300
Cast iron P 2	3.51	2.73	0.83	0.39	—	44.8	310
Cast iron P 3	3.51	2.73	0.83	0.48	—	42.8	318
Cast iron P 4	3.51	2.73	0.83	0.57	—	46.4	315
Cast iron P 5	3.51	2.73	0.83	0.68	—	38.3	310
Cast iron P 6	3.43	2.79	0.83	0.81	—	38.7	310
Deep drawing sheet St.VII 23	0.05	—	0.37	0.006	—	35.1	102
Steel casting not annealed W U	0.16	0.45	0.63	0.085	0.056	39.6	175
Steel casting annealed W G	0.16	0.45	0.63	0.085	0.056	37.9	136
Steel casting not annealed H1U	0.35	0.26	0.66	0.069	0.059	50.0	200
Steel casting annealed H1G	0.35	0.26	0.66	0.069	0.059	41.3	165

As will be seen from this chart, the reductions achieved per pass are by no means smaller than those used in the rolling of certain hard steels. Actually, still larger reductions could be obtained without the occurrence of fissures, by adhering to certain conditions regarding material and the process of rolling. This must be taken as proof that in the near future the distinction between materials that can be rolled and forged and those that cannot, will have to be dropped. Already note should be taken that, in conformity with Nipper's claims, the tensile strength of cast iron can be raised in this way from 18-20 kg. per sq. mm. to 65-120 kg. per sq. mm. with the elongation ranging from 3-12 per cent according to treatment before and after rolling. Nipper is firmly convinced that a large-scale introduction of the new process now depends solely for its realisation upon the active interest of the commercial producer, as there will be no lack of demand for the new product. Unfortunately, his endeavours in this respect have remained without success for more than ten years.

REINFORCED CAST IRON.

A few years ago, it was reported that a watch-tower built at the Newjanks Iron Works (in the Urals) in 1725, upon the initiative of Peter the Great, and still in existence to-day, was found to be built of cast iron armoured with steel. This recent finding is said to have stimulated engineers of the Soviet Union to undertake large scale research into this kind of cast iron "concrete." This research, it is stated, has led to the discovery that the use of a steel reinforcement of some 3-5 per cent by weight of the structure, leads to a 2.5 to 3.5 fold increase in bending strength. Computations are claimed to have shown that armoured cast iron structures are 50-75 per cent lower in cost than ferro-concrete and 35-45 per cent lower in cost than corresponding steel structures. Of the few data available on this type of construction in German literature, mention may be made of the slag ladle of armoured cast iron construction covered by the German design patent No. 1,491,094 issued in 1940 and illustrated in Fig. 5.

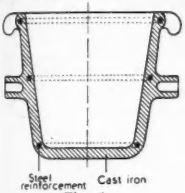


Fig. 5
Reinforced slag ladle.

For some years the author has looked into the problem of incorporating a steel reinforcement into iron castings. It is seen that the higher modulus of elasticity of the steel reinforcement will be able to absorb occurring tensile stresses, thereby relieving the cast iron which, because of its lower modulus of elasticity, will show a greater yield under tensile stress. This phenomenon has been made use of by Messrs. Sulzer Bros., Ludwigshafen (now Halberger Engine Works & Foundry) in the construction of fracture-proof crankshafts. An intimate joint between the reinforcement and the parent metal by welding is of course indispensable to success. But, even so, there often remain the adverse effects originating in the formation of network-like arranged segregation-carbides (see Fig. 6) which because of their hardness and brittleness may lead to premature fractures.

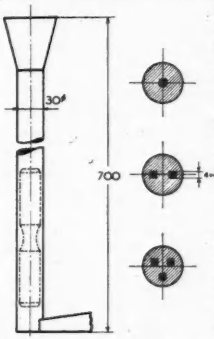
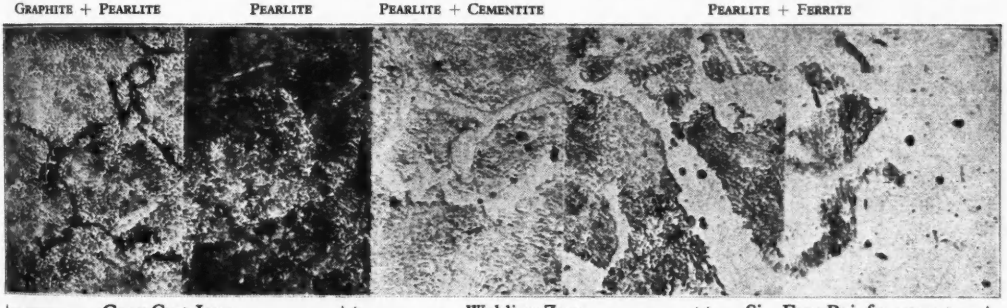
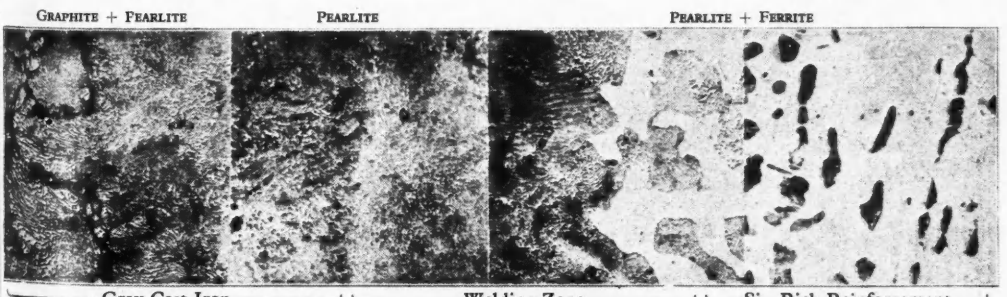


Fig. 8. **Reinforced cast iron. Test specimen.**

According to the author, this danger can be eliminated by the use of a soft, or medium-hard armour steel containing a liberal amount of silicon. This means in effect that the transition zone does not contain segregation-carbide, although segregation-graphite





Figs. 6 and 7. **Transition zones from gray cast iron to reinforcements (× 500).**

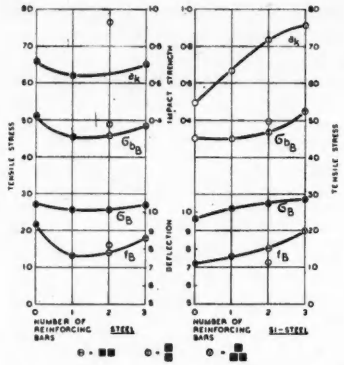


Fig.9

still remains present (Fig. 7). It may be mentioned that it has also been proposed to ensure self-welding by coating the armouring steel with ferro-silicon powder. But the use of high-silicon wrought iron or steel serves also to increase the fracture strength of the cast iron, in so far as the intimate weld produced without the creation of carbidic interzones increases not only the tensile and bending strength, but also the flexure of the material. This has actually been proved by test of the armoured specimen shown in Fig. 8, the actual test data being reproduced in Fig. 9.

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DISTILLATION OF MIXTURES OF COAL-MUD AND COAL.

By M. P. RICHALET, Manager of the Versailles Gas Works. (From *Journal des Usines à Gaz*, Vol. 67, No. 9, 15th September, 1943, pp. 98-99).

IN the month of November, 1942, the Coal Controller of the Seine-et-Oise Department was obliged to accept for his district a large amount of Coal-Mud (Sludge) coming from the Saar district.

We were able to get hold of a certain amount of this to carry out experiments on our own behalf on the value of sludge as a raw material for the manufacture of gas. We distilled this sludge in the first instance in our Laboratory and then proceeded to distil larger amounts in our Works at Versailles and then at the Houdan Gas-works.

Tests in the laboratory.

Undried Sludge. At 1080 deg. C., 100 gr. gave 22.5 litres of gas at 15°.
At 1150 deg. C., 100 gr. gave 31 litres of gas at 15°.

Mean calorific value 4014 cal/m³., i.e., 1,073,000 per ton. Analysis: CO_2 11, O_2 1.4, $H_2$41.4, C_mH_n 2, CO 20.2, $CH_4$15, N_2 9. Humidity 22.5 Fixed Carbon 31.8. Volatiles 22. Ash 23.7. The coke obtained was extremely friable, porous and very badly agglomerated.

The conclusion was that distillation could only be done by mixing the sludge with ordinary coal to ensure agglomeration of the coke. Tests were continued with mixtures of sludge and Bruay coal. (This coal gives 36.2 litres of gas at 15 deg., at 1100 deg. C.: 5042 cal/m³., representing 1,827,700 cal. per ton).

Tests at the Versailles Gas Works.

It was found that vertical chambers were not suitable for distilling the sludge, even when mixed with coal. The fine dust is such that the sludge takes fire as it is falling into the chamber and is volatalised by the heat, so that a large part of it is instantaneously distilled.

The tests had therefore to be carried out at the Houdan Gas Works, where there are horizontal chambers suitable for these trials. The tests were all made in the same retort, the others being filled with coke and the steam cut off. Gas measurements and air control were made on the head of the retort.

1. *Dry distillation.*

(a) Coal only. 150 kg. (3 cwt.) of coal have given the following amount and quality of gas. (Furnace at 1000 deg. C. in roof, pressure nil).

Time from charging	30 min.	1.15 hr.	2 hr.	3.30 hr.
CO_2	6,4	4,8	3,8	2
C_mH_n	4	4,2	4,2	1,2
O_2	0,8	1	1,2	0,6
CO	11	11,2	10,2	10,2
H_2	28,4	32,4	42,2	59,2
CH_4	42,4	39,8	32	15,8
N_2	7	6,6	6,4	11
C.P. (calculated) ..	6 550	6 490	6 010	4 045

Time from charging	1 hr.	2 hr.	3 hr.	4 hr.	4.30 hr.
Output from charging	12,8	25,2	37,9	48,8	50,5
Output per hour ..	12,8	12,4	12,7	10,9	

Volumetric output: 50.5m³ from 150 kg. i.e., 33.7m³ per 100 kg.

(b) Sludge 30%. Coal 70%. (45 kg. sludge; 105 kg. coal). Temperature and pressure as above.

Time from charging	40 min.	1.50 hr.	2.10 hr.	4.10 hr.	5.10 hr.
CO_2	4,8	4,4	2,8	1,6	1
C_mH_n	2,6	2,8	2,2	0,2	—
O_2	0,4	0,6	0,8	0,6	0,2
CO	9,8	10,4	12,2	11,4	12,2
H_2	36,6	53	51,4	67	60,6
CH_4	42,6	24,2	24,8	14,2	4
N_2	3,2	4,6	6,8	5	16
C.P. (calculated) ..	6 330	5 180	5 014	3 850	2 510

Time from charging	1 hr.	2 hr.	3 hr.	4 hr.	5 hr.
Output from charging	10	20,2	31,4	41.1	44,7
Output per hour ..	10	10,2	11,2	9,7	3.6

Yield per 100 kg. of mixture: 30m³.

(c) Sludge 50%. Coal 50%.

Time from charging	45 min.	1.30 hr.	2.40 hr.	3.40 hr.	4.30 hr.
CO_2	9,2	7	5	5,4	3,6
C_mH_n	4	3,8	3	1,8	0,8
O_2	0,4	0,4	1	0,8	0,6
CO	8,6	9,4	10,8	13	14,6
H_2	34,4	47,2	43	54,2	57
CH_4	36,2	24,2	29,2	18	18
N_2	7,2	8	8	6,8	5,4
C.P. (calculated) ..	6 070	6 280	5 400	4 375	4 196

Time from charging	1 hr.	2 hr.	3 hr.	4 hr.	5 hr.	6 hr.
Output from charging	7,5	14,3	21,6	30	36,9	39,5
Output per hour ..	7,5	6,8	7,3	8,4	6,9	2,6

Yield per 100 kg. of mixture: 26.3m³.

(d) Sludge 70%. Coal 30%.

Time from charging	45 min.	1.30 hr.	3 hr.	3.45hr.
CO_2	10,4	9	6,6	2,8
C_mH_n	4,4	3,6	3	0,4
O_2	0,8	0,4	0,4	0,6
CO	8,2	9,6	11	15,8
H_2	33,8	38,6	43	56,4
CH_4	34,4	30,2	28,4	12,4
N_2	8	8,6	7,6	11,6
C.P. (calculated) ..	5 980	5 550	5 350	3 560

Time from charging	1 hr.	2 hr.	3 hr.	4 hr.	5 hr.	6 hr.
Output from charging	7	12,6	19,3	26,8	32,5	34,5
Output per hour ..	7	5,6	6,7	7,5	5,7	2

Yield per 100 kg. of mixture : 23m³.

2. *Steaming.*

The injection of steam produced the same results as regards quality and quantity of water-gas as with coal alone, whatever proportion of sludge was added to the mixture.

The sludge, owing to its large water content, lowers the temperature of the chamber at the beginning of distillation but in a horizontal chamber this does not lead to any lowering of the chamber as a whole.

As regards quality of gas, the influence of the sludge is not very great since with even as much as 70 per cent sludge the calorific power is still 5080 cal/m³. as against 5500 cal/m³. for coal by itself, with dry distillation.

Subtracting the volume of gas produced by the coal in the mixtures, we get the following volumetric output for the sludge :

Per cent of sludge in mixture ..	30.	50.	70.
Output per 100 kg.	21.4	19.1	18.4

Owing to the reduction of temperature by the sludge, the time required for distillation is appreciably increased. Coal by itself was distilled in 4½ hours whereas with 70 per cent sludge the time was 6 hours. This increase is much more noticeable if the weight of the charge of mixture is increased so as to give the same volume of gas as with coal alone, so that the use of sludge diminishes the capacity of the furnace.

Sludge does not coke in large pieces but is found incorporated in the coal coke, to a greater extent when the coal is more fusible. Much of the sludge still remains in the form of dust. The large coke produced from the distillation of mixtures with more than 30 per cent sludge is not suitable for lining producers owing to its large percentage of ash and its tendency to form clinkers. This depends on the fusibility of the coal and the ash content of the sludge used.

It would be advisable for a gas works distilling sludge to use pure coal for the number of retorts necessary to produce coke for the gas-producers and to distill in the other retorts a mixture of coal and sludge in such proportions that the battery of furnaces will keep up a satisfactory volume of production.

The proportion of sludge in the mixture can, moreover, be very much increased if it is possible to carry out a preliminary drying.

Sludge used in these conditions may lead to a large reduction in the coal consumed.

"SOFT SKIN" ON HIGHLY FINISHED SURFACES.

By Dr.-Ing. P. Leinweber, VDI, Berlin. (From *Werkstattstechnik*, *Der Betrieb*, Vol. 37/22, No. 6, June, 1943, pp. 241-243).

It is often claimed by makers of measuring instruments that measuring surfaces have to be lapped not only to obtain high accuracy, but also to remove the soft layer produced by the grinding process, thus increasing the life of the surface.

So far it has not been possible to prove or disprove this statement which apparently is based on practical experience. Any mechanical change of a finely ground surface involves the danger of altering its structure and thus of obtaining wrong results on examining it metallographically.

Whether a soft skin has to be removed by lapping is of greatest importance, this process requiring additional working time and highly skilled labour, but everything must be done to increase the life of measuring instruments.

Method of Test.

A new method was developed by which it is possible to examine test specimens metallographically during the working procedure. An optically flat surface is produced, the material being cut and not broken as by grinding. Thus, it can be assumed that the surface has not changed, or only slightly so. If such a surface is only lightly polished and etched, no rounding at the edges worth mentioning can be observed even at the highest magnifications.

Table I.

Material	No.	Composition %						Heat Treatment
		C	Mn	Si	P	S	Cr	
½ C Io.61	A	0,10	0,40	0,25	0,01	0,02	—	Case hardened at 850°, hardened in oil from 780° and tempered at 220°
Oldi Stabil	B	0,80	2,03	0,29	0,014	0,018	—	Hardened in oil from 750 and tempered at 220°
Agger steel	C	1,39	0,42	0,26	0,021	0,021	1,49	Hardened in oil from 800° and tempered at 140°

Treatment of Test-specimens.

Two specimens (I. and II.), as shown in Fig. 1, were prepared respectively of each of the materials given in Table I. The surfaces f_1 and f_2 were made optically flat by the new method, polished, and etched with a 2 per cent alcoholic nitric acid solution. Then the two parts were firmly screwed together, and the surfaces a_1, a_2 and b_1, b_2 respectively, subjected to rough grinding, finish grinding, and final lapping. Before and after each treatment photomicrographs were prepared of certain points on the surfaces f_1 and f_2; some of these are shown in Figs. 2 and 3. Special measures were taken so as to assemble the two specimens always in the same relative position.

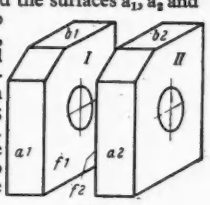


Fig. 1

EXPERIMENTAL PROCEDURE.

The main object was to find out whether a soft skin can be detected when rather unfavourable conditions of grinding have been employed. It was necessary to lap the surface to a great extent in order to ensure that any material that might have changed during grinding had been removed, and structural change due to lapping could be seen.

The following conditions of grinding and lapping were used :

Grinding : Alundum-grinding wheel (Norton) No. 3846 j 8 BE (without coolant) grinding speed 25 m/sec.

Total depth of cut during rough grinding = 5 × 0.03 = 0.15 mm.

Total depth of cut during finish grinding = 5 × 0.01 = 0.05 mm.

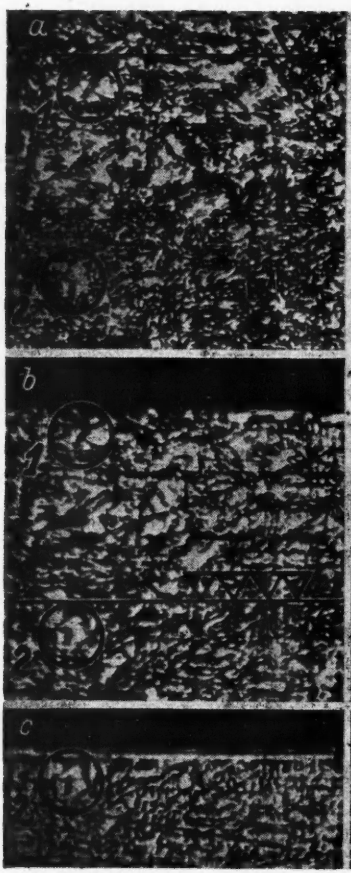


Fig. 2. **Photomicrographs of ground specimen St. C. 10.61 without finish grinding.**

Etched with 2% alc. HNO_3 solution .X 1000. (a) Before rough grinding ; (b) after rough grinding ; (c) after lapping. 1, 2, areas for comparison.

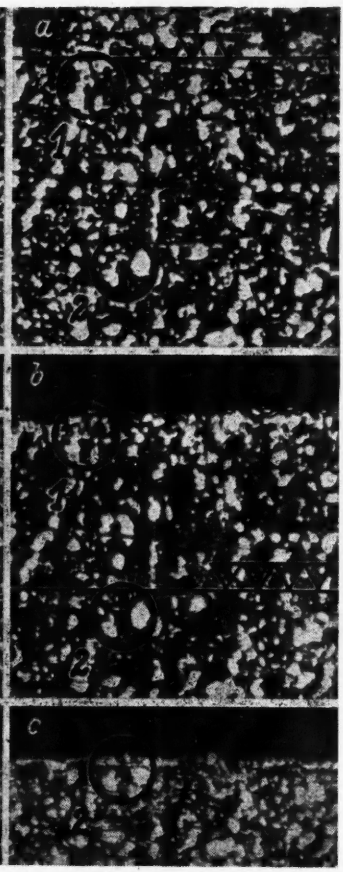


Fig. 3. **Photomicrographs of Poldi Stabil without rough grinding.**

Etched with 2% alc. HNO_3 solution .X 1000. (a) Before finish grinding ; (b) after finish grinding ; (c) after lapping. 1, 2, areas for comparison.

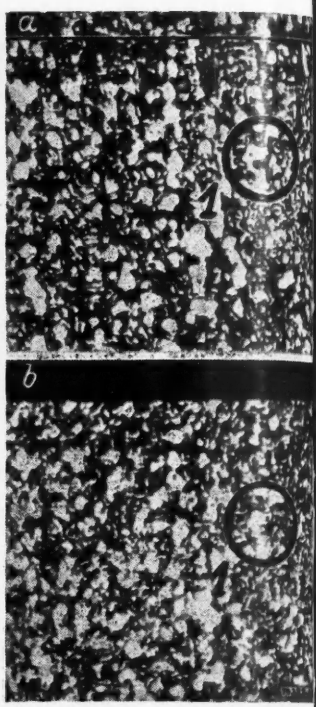


Fig. 4. **Structural change of Poldi Stabil steel as caused by Sawin grinding**

Etched with 2% alc. HNO_3 solution .X 1000. (a) Before Sawin grinding ; (b) after Sawin grinding. (1) Area for comparison.

Lapping : Chromium oxide on cast plate by hand. Total thickness of cut about 30.

Conditions of Test.

The surfaces were examined in the following way :

(1) Hardness measurements of the surfaces *f* near the treated surfaces were carried out with the Zeiss-Hanemann Micro-Hardness Tester. No satisfactory results were obtained as the hardness of the separate constituents of the structure only could be determined, the load being necessarily low.

(2) If there was a soft skin the Vicker's hardness of the surfaces *a* and *b* should have increased with increasing load. These tests were not successful as, with low loads, accurate measurement could not be carried out on surfaces that had been ground only.

(3) Scratch hardness tests of the surfaces *f* near the edges did not prove successful ; the loaded diamond point of the Zeiss Diritest slid off the edge producing too deep a scratch. Placing two equal surfaces together also gave unsatisfactory results.

(4) According to Jünger a soft skin is blackened when etched for a short time with a 3 per cent alcoholic nitric acid solution. Several ground surfaces showed a slight blackening when treated in this way. (To increase the effect of grinding, the total depth of cutting during rough and finish grinding was 2×0.05 and 2×0.01 mm. respectively). The blackened layer was removed with the finest grade emery paper and the etching process repeated. This procedure was repeated until no blackening took place. The thickness of the soft skin found in this way was roughly 1 to 2 microns.

Agger-steel (Material C in Table I.) gave no positive results. As its structure is very fine it had to be polished to a great extent to give satisfactory photomicrographs ; thus the edges were slightly rounded, and subsequent working resulted in a burr which interfered considerably. Also with the other specimens, in spite of screwing them firmly together, a small gap was observed between the surfaces *f* after grinding, this gap resulting in the formation of a small burr.

A comparison of the photomicrographs in Fig. 2 (material A) shows that the separate constituents of the structure can be well distinguished up to about 2 to 3 mm. from the edge. No structural changes can be observed. If any change in the zone at the edge has taken place and, if such a change does not just appear to have taken place because of the burr, then the thickness of this zone is at the most 2 to 3 microns. No noticeable change of the structure was caused by lapping. Fig. 3 (material B) shows fundamentally the same result.

In contrast to this Fig. 4 shows the change in structure through a depth of 10 mm. (corresponding to 10 microns), the material having been ground with a carbide disc of the Skoda-Sawin wear testing machine.

Conclusions.

If under normal grinding conditions a " soft skin " is formed, and if this can be detected metallographically, then its thickness is at the most two to three microns.

As hardness and resistance to wear are not necessarily in agreement, the question still remains open whether the resistance to wear is not lower at a depth larger than two to three microns, without it being possible to show this metallographically or by hardness testing. As X-ray examination is not possible because of the heat treatment of hardened specimens, the only possibility remaining is to detect any structural changes by means of electron interference. It is however, probable that the larger wear of the unlapped surfaces is due to their greater roughness.

Because of the small zone in which the existence of a soft skin is possible, to-day measuring surfaces should not be lapped. Only gauges with very small tolerances where great accuracy is required should be lapped.

THE SOVIET W2 TANK DIESEL.

By AUGUSTIN. (From *MTZ, Motortechnische Zeitschrift*, Vol. 5, No. 617, July, 1943, pp. 207-213).

(Continued from our previous issue).

A SECTION through a cylinder showing the light metal (silumin) cylinder head and the wet liner is given in Fig. 9. Each cylinder block is of light metal, the composition of which was given in Table II. of the previous article, comprises six cylinders, has a height of 25 mm. and a weight of 51 kg. The cylinder liners of 4 mm. thickness are pressed into place with a water seal at their lower ends being effected by rubber packing. Sufficient strength is obtained by the provision of circumferential outer ribs of 4 mm. width. In axial direction the distance between adjacent ribs varies from 11 mm. at the top to 7 mm. at the bottom. The integral flange of 5 mm. thickness at the upper end of the liner is 14 mm. larger in diameter than the liner proper. As shown in Fig. 9 at the lower end the liners extend from the cylinder block, the free length being 56 mm. Machining of the block is confined to the faces contacting with cylinder head and crank case respectively. While no seal is provided between the abutting surfaces of cylinder block and crank case, the joint between cylinder block and head is made with a 3 mm. thick gasket of pure aluminium. To ensure a better seal and to avoid blowing out of the gasket, the respective joint surfaces are provided with gramophone finish.

The upper face of the cylinder block contains 24 holes of 11 mm. diam. which serve as passages for the cooling water. Water tightness of these passages at the flanged joint is ensured by rubber rings of 24 mm. diam. and 6 mm. height, these rings being contained in corresponding holes punched into the aluminum gasket (see Fig. 10). The cylinder heads for each group of 6 cylinders are made in one casting of silumin and are provided with the necessary openings for admission and exhaust valves. In order to avoid danger of leakage, the tie bolt connection between cylinder head and cylinder block is reinforced by 26 stud bolts of 8 mm. diam. bolting the head to the cylinder block. Again referring to Fig. 9, the injection nozzle is arranged centrally within the combustion space ; while the compressed air starting connection will be found at the left hand side of the cylinder head. The bevel gear drive shafts between crankshaft and cam shafts are carried at their upper ends in bearings of which the supports are bolted to the cylinder heads, while the bearing supports for the cam shafts are attached to the cylinder heads between the valves, there being seven bearings in each row.

The cooling water admission to the cylinder is arranged at the lower part of the rear of the engine, and the exhaust is placed at the front end. Each row of cylinder heads is covered with a light alloy cast hood, shown in Fig. 9, which also shows the shape of the piston.

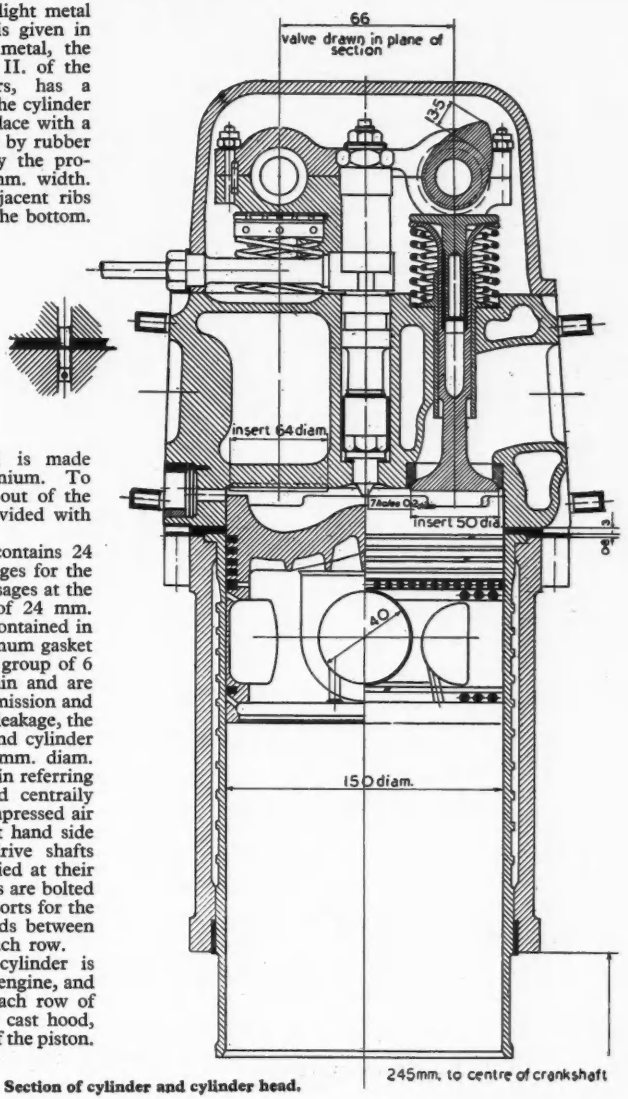


Fig. 9. Section of cylinder and cylinder head.

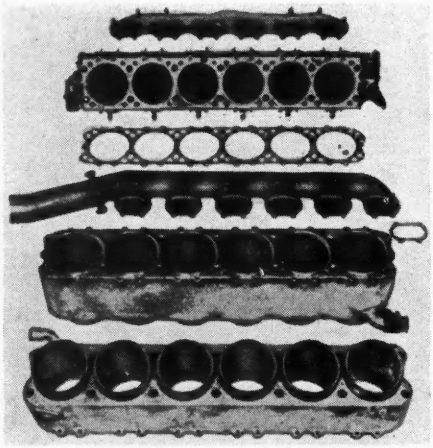


Fig. 10. **Parts of cylinder block and cylinder head.**

The piston diam. is 150 mm. and the height of 120 mm. represents a typical aero type. There are six rings per piston, five above and one below the gudgeon pin. The latter is 45 mm. from the bottom edge of the piston skirt, and has a cylindrical bore. The measured Brinell hardness over the piston surfaces is given in Fig. 11. Two inlet and two outlet valves are provided per cylinder, which all differ in detail. This is in contrast to the trend otherwise displayed towards effecting greatest possible standardisation of design. The adjustment of valve play is made similar to that of the Hispano-Suiza engine, the accuracy of adjustment being 0.01 mm. Valve timing is as follows:

Commencement of admission before top end of stroke	20 deg. $\pm$3 deg.
Termination of admission after bottom end of stroke	48 deg. $\pm$3 deg.
Commencement of exhaust before bottom end of stroke	48 deg. $\pm$3 deg.
Termination of exhaust after top end of stroke	20 deg. $\pm$3 deg.

Valve play : Admission 0.4 mm.
Valve play : Exhaust 0.6 mm.
Firing order 1_l-6_r-5_l-2_r-3_l-4_r-6_l-1_r-2_l-5_r-4_l-3_r

As Fig. 9 shows, no valve levers are employed, the cams act directly upon the valve stems. This has been achieved by placing the cam shafts immediately above the cylinder heads. The cam shafts are bored hollow in order to effect an efficient supply of oil to the cams as well as to the camshaft bearings.

It has already been mentioned that the injection pump is a replica of the German Bosch pump PE 12B, although a few parts of the Russian pump are made slightly stronger. However, all parts subjected to wear have been copied with such an accuracy—particularly the plunger elements and the pressure valves—that they can be interchanged with corresponding parts of German make. The injection nozzle of the Soviet engine corresponds to the Bosch nozzle DL140 S204 with seven parts of 0.2 mm. diameter each.

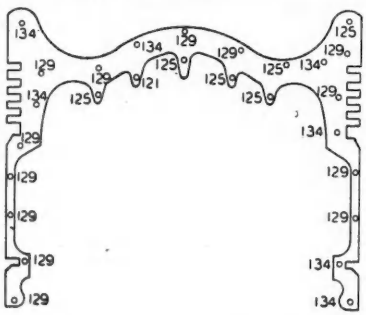


Fig. 11. **Brinell hardness of piston.**

The pressure at the commencement of injection is 200 atmos. A notable feature of the Russian injection pump arrangement is the draining of leakage oil into the crank case. The fuel filter is also built like the German model.

The fuel pump is of the rotary blade type, the blades sliding in an eccentric rotor in the usual manner. The cooling water pump is of the centrifugal type with an overhung six-bladed impeller of bronze carried on one side by a ball bearing. The gland of this pump is shown in Fig. 12. It will be noted that there are two packings, one being the water seal and the other constituting the oil seal on the crank case side. Both packings are pressed home by means of a helical thrust-spring placed between them, the space containing the spring is seen to be vented. Suction and delivery lines are 37 mm. interior diam. The pump is driven over a reducing gear with a ratio 1:1.5.

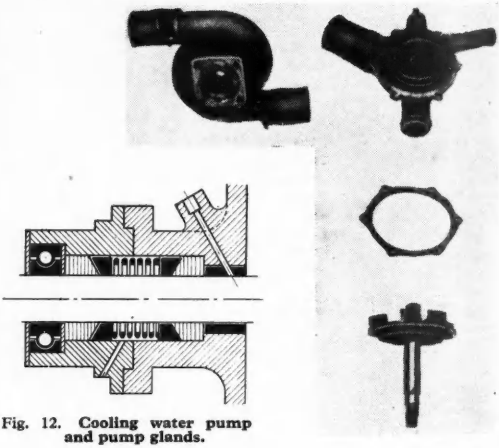


Fig. 12. **Cooling water pump and pump glands.**

A lubricating pump of the gear type is driven from the crankshaft over a bevel gear transmission of the ratio 1:1.725. At an engine speed of 2000 r.p.m., oil delivery is 76 litres. The engine starter is rated at 15 h.p. at 24 V, its speed being 150-200 r.p.m. Compressed air starting is, however, also provided. It consists of a compressed air container, a distributor with 12 starting valves and the requisite piping. A compressor for replenishing compressed air supply is not provided. The compressed air distributor is similar to that of the French firm of SOMUA. Admission of compressed air for starting is timed at about 3-6 deg. after top end of stroke. The distributing system is shown in Fig. 13.

The lubrication system is of the commonly used type, the filtered oil being passed to the rear main bearing of the camshaft. Here it enters the hollow crankshaft through three bores of 8 mm. diam. and passes on to all the main and crank bearings. Oil is also conveyed to fuel pump and generator as well as to the skew gear transmission shafts between crankshaft and camshafts. Pressure in the oil mains prior to admission to the first main bearing is kept at 6-9 atmos. g., care being taken that the oil pressure does not fall

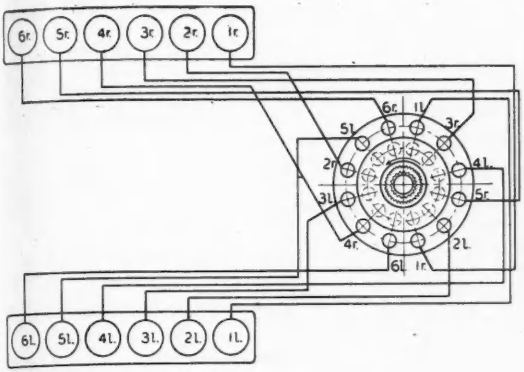


Fig. 13. **Compressed air distributing system.**

below 1.5 atmos. g. at any point in the lubrication system. An oil pressure gauge is provided on top of the lubricating pump.

Cooling water is delivered from the circulating pump to the two cylinder blocks where it passes into the space between block and cylinder. From there the water passes on through the cylinder heads via the 24 communicating passages. Water distribution is so arranged that local overheating cannot occur, each cylinder head is provided with a steam vent, the individual vents being connected to a common equalising chamber. Both cylinder rows are equipped with coil coolers. Cooling the circulating water is carried out by the use of centrifugal blower, placed on the crankshaft (Fig. 14) to which it is coupled through friction disc and gear drive. The blower wheel has 30 blades, the outer wheel diam. being 872 mm., with the blading being 182 mm. in height.

Weights of the engine components are as follows:

Crank case upper part	137.0 kg.
Crank case lower part	24.5 „
Crankshaft	66.9 „
Cylinder head	29.0 „
Cylinder block	51.0 „
Cam shaft	4.5 „
Cylinder hood	6.3 „
Piston and gudgeon pin	3.82 „
Main connecting rod	5.95 „
Aux. connecting rod	2.0 „

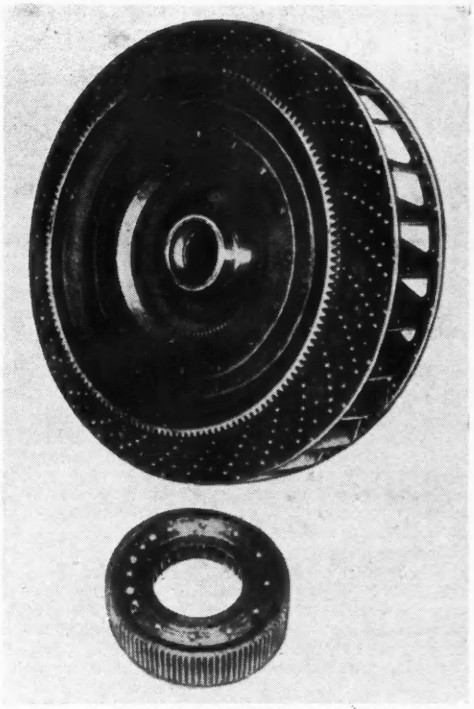


Fig. 14. **Fan wheel.**

Wrist pin of aux. connecting rod	0.6 kg.
Fuel injection pump	35.5 „
Generator	36.0 „
Cooling water pump	3.5 „
Lubricating oil pump	5.5 „
Fuel pump	1.7 „
Oil filter	3.27 „
Fuel filter	2.8 „
Exhaust manifold	5.5 „
Intake manifold	4.5 „
Total engine weight	811.74 kg.

STARTING OF LARGE ENGINES. IMPORTANT PROGRESS: THE INERTIA STARTER.

(From *La Vie Automobile*, Paris, Vol. 39, No. 1261-1262, 10th and 25th October, 1943, pp. 241-243).

WHILE the problem of starting automobile engines is completely solved to-day by the employment of the electric starter, the position is altogether different in the case of large diesels or producer gas engines. The reason for this will readily be recognised if it is recalled that diesel and producer gas engines are units of relatively large size, and operate with higher compression ratios than petrol engines. Electric starting of such engines would, therefore, require a starting motor of considerable size and weight, together with an expensive storage battery. Furthermore, producer gas engines are difficult to start, often requiring several attempts leading to premature exhaustion of the storage battery. The conclusion must, therefore, be drawn that large engines of commercial vehicles should be provided with a mechanical means of starting which will not impose limitations upon the repetitions of starts. The solution to this problem is found in the inertia starter, known by its universal application to aircraft, which is capable of starting aircraft engines of 1,500 h.p. and more.

The principle of the inertia starter consists in the utilisation of kinetic energy possessed by a flywheel brought to a very high speed of rotation by means of a hand crank, the speed of the latter being geared up by a high ratio reduction gear. The salient features of an inertia starter of this type are shown in Fig. 1. Here the hand crank (not shown) is attached in the usual manner to a shaft *M* of the reduction gear train.

Once the flywheel has been brought up to speed, the starting operation is effected by throwing in the clutch *G*, by pressing the button *B*. In order to preclude damage to the engine by impact, a flexible coup-

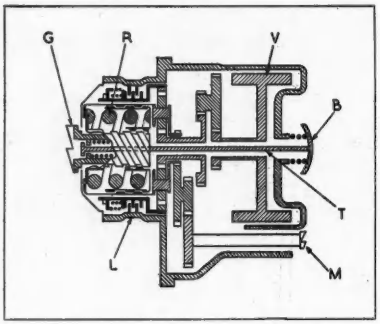


Fig. 1

ling is interposed. As will be seen from the illustration, when the clutch *G* engages with that of the engine, the latter offers a resistance which immobilises the clutch. But the assembly continues to rotate while screwing down, at the same time compressing the spring *R* by means of the travelling nut moving along the starter shaft, and thus increasing the thrust of the spring upon the friction disc of the clutch.

In this way the torque exerted upon the engine is gradually built up from zero to its full value, a further advantage being that the clutch remains engaged. As a matter of fact, the increase in torque to which the starter coupling is subjected during the compression stroke increases the spring compression. During the expansion stroke, on the other hand, the clutch will tend to disengage itself because of the acceleration of the engine. Disengagement, however, cannot take place, as at this moment the thrust spring slackens, allowing a relative acceleration of the coupling half of the starter. The jerks which would otherwise be inevitable in the case of four or six cylinder engines are thus prevented. Because of the greater uniformity of torque experienced with multi-cylinder engines, the need for a flexible coupling between inertia starter and engine will not be so indispensable. An additional advantage inherent to the friction clutch is that when the engine has seized, the clutch will slip, although the spring is wound tight and is exerting its maximum thrust.

Once the engine has started, the driver ceases to press the starter button, and the coupling half of the starter is kept at rest by means of a small spring, as shown in the illustration.

In another type of inertia starter, the flexible coupling is provided by a rubber coupling.

Referring again to the illustration, it will be seen that a multiple disc clutch equipped with bronze and steel discs is also provided.

In the case of lorries and buses, the inertia starter is mounted directly on the engine at the end of the crankshaft, and in a number of engines provision has already been made for its installation.

It is interesting to note the test results obtained with a five litre engine equipped with an inertia starter. To bring the starter up to speed by turning the hand crank, one minute and 50 seconds was required. The total weight of the starter amounted to 25 kg. The flywheel weighed 4 kg. and the energy that would be stored in it was 1500 kg.-metres. This enabled the starter to exert a torque of 120 metres-kg. at 120 r.p.m. and was sufficient to crank the engine twelve times in cold weather ; under normal conditions the device is powerful enough to effect four or five successive starts. If this is still insufficient to start the engine, renewed cranking of the inertia starter is all that is required, and immobilisation of the vehicle because of a run-down battery need never be feared.

In another test conducted at a temperature of 2 deg. C. on a tractor equipped with a 5.2 litre producer gas engine with a compression ratio 1:7, 70 revolutions of the hand crank in one minute sufficed to crank the engine 10-12 times. This was equivalent to four starts, since the engine was started after the third turn. Yet another test was concerned with the starting of a 12 litre 4-cylinder tractor diesel engine with a compression ratio of 1:15. With the maximum torque of the starter limited to 110 mkg., the engine could be started after 4 turns, the outdoor temperature at the time being 10 deg. C.

A NEW HYDRODYNAMIC PRINCIPLE OF SOUND MEASUREMENT.

By PROF. H. ZICKENDRAHT. (From *Swiss Technics*, Vol. 22, No. 2, May-June, 1943, pp. 8-9).

THE Gasjet Phonometer developed by the author, works on the principle of amplification and rectification. The physicist has known for many years the high sensitivity to small disturbances of stationary and moving liquids. The surface of a jet of gas (air, oxygen, carbonic acid and even household gas) emerging from a suitably shaped nozzle into the undisturbed atmosphere, is extraordinarily sensitive to any disturbance of equilibrium. The author discovered that the small vibrations occurring when sound is produced suffice to exercise such a strong action on the jet that even relatively insensitive phonometers are delicate enough to prove the presence of sound, and also to measure it if the instrument is suitably designed.

The Gasjet Phonometer consists of a specially formed fine nozzle, mainly of elliptical cross section, from which gas at low pressure (mostly air from a pressure cylinder with a reduction valve) is emitted. Two or three centimetres from the nozzle, the jet is trapped by a Pitot tube, so that the pressure in the jet can be measured and thus also the velocity of the gas can be measured with the help of a sensitive manometer in the usual manner. If sound falls vertically to the surface on to the gasjet immediately above the nozzle, the limitation surface between moving and stationary air is made to undulate. This movement is now amplified along the jet stream, between the nozzle and the trap disc, to such an extent (several thousand amplifications) that in consequence of an eddy formation which has the effect of rectification, the pressure in the jet is so greatly reduced that the alcohol column in the manometer may be displaced several centimetres to the right.

In comparison with phonometers consisting usually of a microphone, a tube amplifier with rectifier and flow gauge, the Gasjet Phonometer is very simple. When taking sound measurements with it, first a steady jet of air is directed from the nozzle to the Pitot tube. The micromanometer then registers maximum displacement, e.g., 50 graduations. If sound now falls upon the section immediately above the nozzle aperture in form of clear notes or noises of any kind, the jet pressure is at once reduced at the trap disc of the Pitot tube, and the indicator of the micromanometer recedes. The scale can be graduated according to the frequency and amplitude of the incoming sound. According to the length of the jet, the range between 300 and 3,000 Hertz or, alternatively, between 2,000 and 11,000 Hertz, can be measured with one and the same phonometer. The phonometer can also be used in the sphere of ultrasound. Measurements have so far been extended to a frequency of 16,000 Hertz.

BLOW-HOLE FORMATION IN OXY-ACETYLENE WELDING OF ALUMINIUM ALLOY Al-Mg. 7.

By DIPL. ING. TH. RICKEN and DR. H. GAGEL. (From *Zeitschrift des VDI*, Vol. 87, No. 31/32, Aug. 7, 1943, p. 509.)

WHEN welding small diameter tubing of aluminium alloy Al-Mg 7, which is somewhat difficult to weld, blow-holes were occasionally observed on the internal tube surface. Although the strength of the weld is not impaired, the occurrence of blow-holes must be considered as a sign of faulty workmanship. The cause of the fault has been traced at the laboratory of the Association of German Metal Works by tests made with Heddenal 7, which, according to German Standard Specification DIN 1713, corresponds to Al-Mg 7. All welds were made with the oxy-acetylene flame using a small amount of excess acetylene. A thin paste of Hydrogal was used as flux and applied to both the seam and the welding rod. Where welding rod was used, its thickness was chosen equal to the thickness of the material.

Welding of Sheet.

Since with flat pieces, natural cooling conditions are less complex than in the case of tubing, tests were conducted on aluminium sheet first. In order to ascertain the identity of composition of the material, thinner sheets were obtained by rolling-out a thicker sheet. The weld formation on 4 mm. sheet was studied by forming a weld deposit on the face of the solid sheet while backings of iron, copper, and firebrick were alternatively employed. When using the iron backing, small densely packed blow-holes were found to occur; while with the copper backing, none or only negligibly small, blow-holes were formed. With the use of firebrick backing, however, the blow-hole formation was particularly strong. No difference in blow-hole formation was noted between sheets which had or had not been pickled.

The tests indicated clearly that blow-hole formation is fostered by the heat insulating action of the firebrick backing, while the high thermal conductivity of the copper ensured a rapid removal of welding heat, thus suppressing blow-hole formation.

In butt-welding tests on a 4 mm. sheet, the first portion of the seam was made at the customary speed without any backing at all, while the second portion was made at reduced welding speed combined with the use of a firebrick backing. Referring to the accompanying illustration, it will be seen that, in spite of unchanged conditions, blow-hole formation is found to vary in intensity when using the firebrick backing. But whenever blow-holes occur, the cause must be looked for in deficient heat removal. Similar observations were made during the welding of 1.8 and 1.0 mm. sheet.

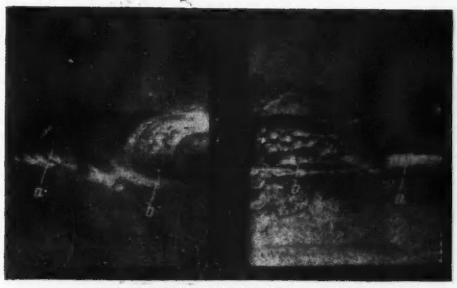


Fig. 1. **Butt-welding of 4 mm. sheet.**
(*a*) Welded at customary speed; (*b*) Welded at reduced speed.

Welding Test on Tubing.

Using tubing of 36 mm. outside diameter and about 4 mm. wall thickness, a seam weld of 50 mm. length and a deposit weld of the same length were made. No blow-hole formation, either external or internal, occurred. The same tubing was reduced by cold drawing to 30 × 2.5 mm. and 27.6 × 3.8 mm. respectively, and the welding tests repeated, again without causing blow-hole formation. The same negative result was registered with tubing of 22 mm. dia. and 2.5 mm. wall thickness. However, when the tube dimensions were further reduced by drawing to 16.2 × 2.1 mm., blow-holes due to excessive heating were formed on the inner wall when making a longitudinal weld with a welding tip of 0.5—1.0 mm. No blow-holes were caused with the use of a welding tip of 0.2—0.5 mm.

Rather large blow-holes appeared on the inner tube wall when butt-welding two tubes of 16.2 × 2.1 mm., each 80 mm. in length, a tip of 0.5—1.0 mm. being used. But in this case also no blow-holes were caused with a tip of 0.2—0.5 mm. When butt-welding a piece of tubing 20 mm. in length to another piece of 200 mm. length, both internal and external weld surfaces were covered with blow-holes; while only a few blow-holes appeared on the longer piece immediately adjacent to the weld. This again proves that the formation of blow-holes is due to insufficient heat removal and consequent overheating. Where the underside of the weld is not left free to radiate heat, a copper backing should therefore be used, and also, in order to prevent undue heating of the material ahead of the weld, a high welding speed should be used, while the flame should be made to impinge upon the material as obliquely as feasible.

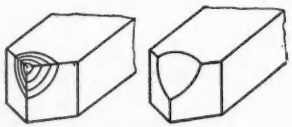
TEMPERATURE DISTRIBUTION IN LATHE CUTTING TOOLS.

By G. PAHLITZSCH VDI, and H. HELMERDIG VDI. (From *Zeitschrift des VDI*, Vol. 87, Nos. 35-36, September 4th, 1943. pp. 564-571.)

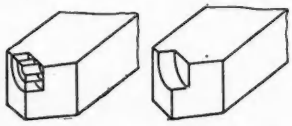
IN their recent resumé of experiences made with the measurement of cutting edge temperatures by means of thermocolours, H. Schallbrock and M. Lang* state that the effects of pressure, temperature, and wear upon tool life depend upon the nature and conditions of the cutting process as well as upon those of the work piece. Among these factors, the temperature effect occupies a special position, insofar as its elevation can be immediately used as a measure of the machinability of steel and alloy steels.

It will, therefore, be readily understood that everything has been tried to measure the cutting edge temperature as accurately as possible. Because of the inaccessibility of the cutting point, however, direct temperature measurement is highly difficult, and completely reliable test results have not, therefore, been obtained as yet. But frequent attempts have been made to measure, by various means, the temperature distribution in the proximity of the cutting point with the highest possible accuracy, and to derive therefrom the cutting edge temperature by extrapolation. These investigations were made on the assumption of a steady state of temperature distribution, while in reality an unsteady heat flow prevails. However, graphic representation of the heat flow can be accomplished without

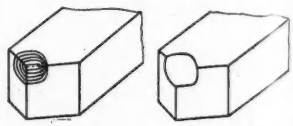
* *VDI-Zeitschr.*, Vol. 87, 1943, p. 15.



Figs. 1 and 2. **Spherical heat flow.**



Figs. 3 and 4. **Cylindrical heat flow.**



Figs. 5 and 6. **Combined spherical and cylindrical heat flow.**

undue difficulty with the use of the incremental method developed by E. Schmidt† and amplified by H. Pfriem.‡

APPLICATION OF THE INCREMENTAL METHOD TO A LATHE CUTTING TOOL. THERMODYNAMIC FUNDAMENTALS.

The phenomenon of heat flow through a plate from the hot side to the cold side, accompanied by heat absorption of the plate material proper is expressed by a partial differential equation of the second order. For a plate or bar this equation is given in simplified form as $\frac{\partial \vartheta}{\partial t} = \alpha \frac{\partial^2 \vartheta}{\partial x^2}$. Corresponding equations can be established for axially or radially outward heat flow in cylinders and spheres, namely,

$$\frac{\partial \vartheta}{\partial t} = \alpha \left(\frac{\partial^2 \vartheta}{\partial x^2} + \frac{1}{x} \frac{\partial \vartheta}{\partial x} \right)$$ for a cylindrical body, and

$$\frac{\partial \vartheta}{\partial t} = \alpha \left(\frac{\partial^2 \vartheta}{\partial x^2} + \frac{2}{x} \frac{\partial \vartheta}{\partial x} \right)$$ for a sphere.

Referring to the case of a cutting tool, the following definitions apply :—

ϑ = temperature in degrees C. after the cutting time t at point x.
t = cutting time, hours.
x = distance of point considered from point of origin.
$\alpha = \lambda / c.\gamma$ = thermal diffusivity of the material.
λ = thermal conductivity of the material.
c = specific heat of the material.
γ = specific weight of the material.

While the analytical treatment of these equations meets with considerable difficulty, the replacement according to Schmidt of the differentials by the finite increments Δt (time increment) and Δx makes possible their graphic evaluation. This method has been further simplified and extended by H. Pfriem, whose method of constructing the temperature distribution curve is employed in this investigation.

Simplifications.

In order to be able to subject the cutting point of the tool to thermodynamic investigations, it must be assumed to possess a shape capable of analytical treatment. The correct choice of such " substitute bodies," however, constitutes one of the greatest obstacles to the solution of the problem. In consideration of this fact, the following abstractions were introduced :—

(1) The point of the tool represents the segment of a sphere and a small but finite zone of given constant temperature existing in the centre of the sphere, the temperature level corresponding to that prevailing at this point of the cutting edge. From this zone, the heat is evenly dispersed in all directions (Figs. 1 and 2).

(2) With great depth of cut, it would seem that actual conditions are better approximated by assuming the heat to emanate from a very thin cylinder of finite diameter from which the heat is distributed in radial direction (Figs. 3 and 4).

(3) Actual average cases will represent a combination of the two simplifying assumptions (1) and (2), the heat being spread in spherical manner from a cylinder of relatively great length (Figs. 5 and 6).

(4) For later reference it should be kept in mind that the cutting tool can be considered part of a sphere or cylinder only to a limited extent, since with increased distance from the cutting edge, its section changes into rectangular contour.

The following points must also be kept in mind :—

As boundary condition it is assumed that at 0.1 mm. distance from the cutting edge, the temperature of the tool during cutting may remain constant at 540 deg. C. at the commencement of the test. Furthermore, for the sake of simplicity, heat losses by convection and radiation during the cutting process are assumed to be negligible.

The finite thickness increment Δx for steel is found on the basis of the following numerical values applying to average steel—

λ = 40 kcal. per metre per hour per deg. C.
c = 0.114 kcal. per kg. per deg. C.
γ = 7,820 kg. per cu. metre.

$$\alpha = \frac{\lambda}{\gamma . c} = \frac{\text{40 kcal. per metre per hour per deg. C.}}{\text{7820 kg. per cu. metre . 0.114 kcal. per kg. per deg. C.}} =$$
$$= 0.0443 \text{ cu. metre per hour.}$$

With a time increment of $\Delta t = \frac{1}{120}$ hour it is

$$\Delta x = \sqrt{2 \alpha \Delta t} = \sqrt{2.0.0443 . \frac{1}{120}} = 0.0272 \text{ metre} = \text{approx. 27 mm.}$$

DETERMINATION OF THE INCREMENT SCALE.

In view of the complex distribution of the heat flow throughout the irregular shapes involved, it is necessary to establish an appropriate increment scale. For this purpose, it may first be assumed that the heat spreads out in the manner outlined in Figs. 3 an 4. In spite of the fact that with a cutting depth of 1 mm. this simplification shall be assumed to hold true only for a value of x = 2 mm. at the most, the temperature found in this way will still be somewhat excessive, as no account is taken of the heat drain in the axial direction.

In order to be able to ascertain the heat distribution after a cutting time of t = 5 min. on the basis of radial flow from a cylindrical body, the determination of an adequate scale for the abscissa of the distance-temperature diagram is necessary. Since the time increment Δt = 0.5 min. was chosen, Δx, to be plotted on the logarithmic scale, must be chosen as approximately 27 mm., as shown in Fig. 5.

From the 10th to the 17th mm.—the latter coinciding with point (1)—the heat distribution shall be assumed to proceed in the spherical manner indicated in Figs. 1 and 2. Consequently, the scale is to be arranged in such a manner as to distort the distance between the 10th and 27th mm. according to a reciprocal scale, as shown in Fig. 7b. In order to provide a transition zone over the distance from the 2nd to the 10th mm., the

† For a description of the Schmidt method the reader is referred to—
T. K. Sherwood and C. E. Reed: *Applied Mathematics in Chemical Engineering*, McGraw-Hill Book Co., 1939, pp. 241-255, while a short summary of the method will be found in
W. H. Adams: *Heat Transmission*, McGraw-Hill Book Co., 1942, pp. 39-42.—The Editor.

‡ *VDI-Zeitschr.*, Vol. 86, 1942, p. 703.

abscissa scale is made a compromise between the two different scales used so far. Furthermore, in order to align the charting of the finite increment Δx to the scale decided upon, the points 2, 3, 4, etc., must be established on the abscissa according to a certain scheme. In this case also a scale is employed which is a hybrid between logarithmic and reciprocal scale corresponding to cylindrical and spherical heat distribution respectively (see Figs. 7a, 7b and 7c).

While the investigations of Schallbroch and Lang, made at the Munich Technical University, led to success in measuring the *temperature* of the cutting edge by means of temperature-sensitive colours, the investigations of the authors were undertaken with a view to acquiring information relating to the *heat absorption* of the cutting tool. For this reason the authors resorted to the use of colours reacting at low temperatures. In this case the zones of colour change under the influence of temperature extend over a distance of approximately 65 mm. from the cutting point; and from the 27th mm. onward, the tool is therefore considered as a bar (in thermal respects). Accordingly, from this point onward, the abscissa is furnished with a linear scale, the layer increments being $\Delta x = 27$ mm. (Fig. 7d).

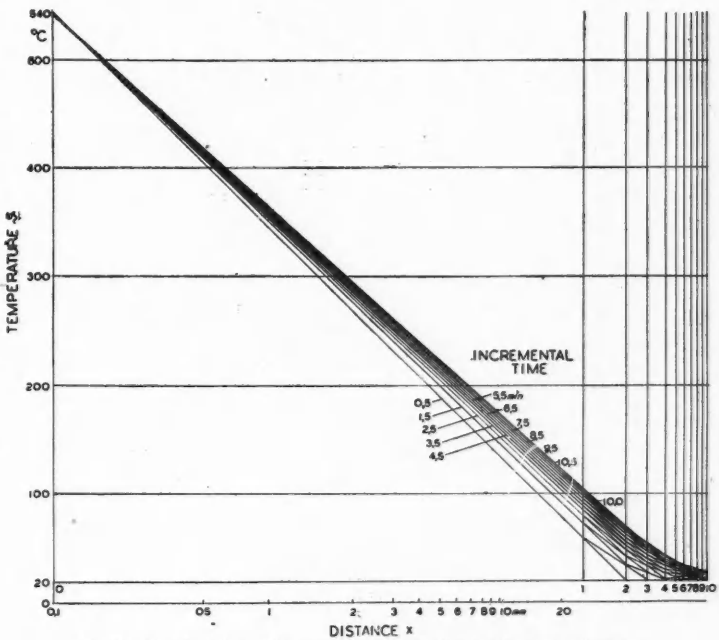


Fig. 8. **Construction of incremental times using scale given in Fig. 7.** Distance versus Temperature diagram.

Construction of Time v. Temperature Distribution Graphs.

With the use of the incremental method the time curves shown in Fig. 8 can be easily drawn. These curves, drawn for time intervals of 0.5 to 10.5 min. after commencement of the cutting operation, indicate the temperature distribution prevailing throughout the tool at the time concerned. The same diagram, redrawn in simplified form and to linear scale co-ordinates is shown in Fig. 9. If it is required to know the temperature prevailing at a given distance and at a given time, the diagram in Fig. 10 can be conveniently used. In itself, it is simply a variant of Fig. 9.

In order to ascertain whether and to what extent the temperature distribution agrees with experimental data, a comparison is made of the theoretical data with the test data obtained by Schallbroch and Lang with the temperature-sensitive colours. The latter data refer to a cutting speed of 23 metres per minute. As will be seen from the subjoined table containing the theoretical and experimental data in juxtaposition, the corresponding temperature values agree well over the range from the fourth to the ninth increment. The existing discrepancies may well be explained by inherent inaccuracies of the experimental method. In Fig. 11 the same data are shown in graphic representation. Both on the basis of theoretical and practical considerations, the authors conclude that the temperature-sensitive colour method may be adjudged most suitable for practical purposes, but lacks the accuracy required in precision measurements. Which of the two methods should be employed in a given case must be decided by weighing the laboriousness of the theoretical method against the errors incurred with the experimental method.

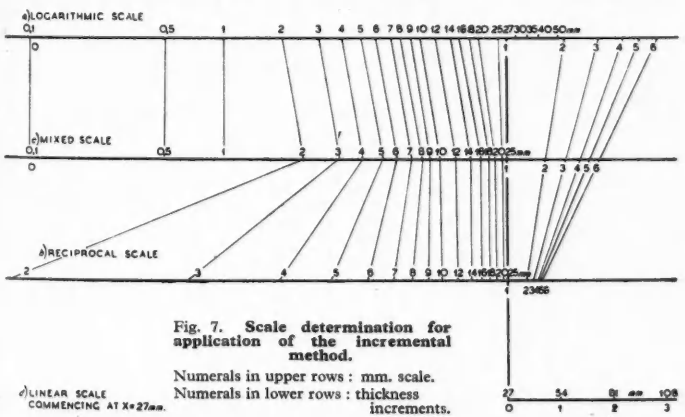


Fig. 7. **Scale determination for application of the incremental method.**
Numerals in upper rows: mm. scale.
Numerals in lower rows: thickness increments.

COMPARISON OF THEORETICALLY OBTAINED VALUES WITH THOSE REPORTED BY SCHALLBROCH AND LANG.

Theoretical Values based on t = 5 min. cutting time.		Experimental values obtained with the use of heat-sensitive colours, based on t = 5 min. cutting time.	
Temperature °C.	Distance x mm.	Temperature °C.	Distance x mm.
74	49	—	—
96	22.5	—	—
119	15.5	—	—
163	8.7	155	8.8
183	6.7	190	6.0
233	3.6	235	3.8
293	1.85	305	2.6
<350	≈ 1.0	370	1.8
447	0.3	470	0.7

THERMAL CONSIDERATIONS.

THE AMOUNT OF HEAT ABSORBED BY THE TOOL.

Having thus clarified the problem of heat conduction and the temperature increase of the tool, a study of the interrelationship between the heat produced by the cutting process and that absorbed by the tool will be interesting. Notwithstanding the high metal temperatures obtaining at the cutting point of the tool which eventually terminate its service life, only small amounts of heat are actually absorbed. This is due to the fact that the contact surface of the tool with the piece is small when compared to the physical dimensions of the tool as such. As reproduceable precise data are not available, a few data obtained by the authors may be given here, but these data should be considered subject to revision.

Test Procedure.

A heat-insulated lathe cutting tool was painted with the various temperature-sensitive colours required. In the test itself an accurate record was made of the times at which respective colour changes occurred at certain marked points. An effort was made to keep the cutting speed as uniform as possible. The cutting tool was a high speed tool steel of rectangular shape, its section measuring 13 x 24 mm. The work piece was a steel of medium strength. The cutting test extended over t = 16 minutes, cutting speed being v = 20 metres per minute, while the product of *depth of cut* x *feed*

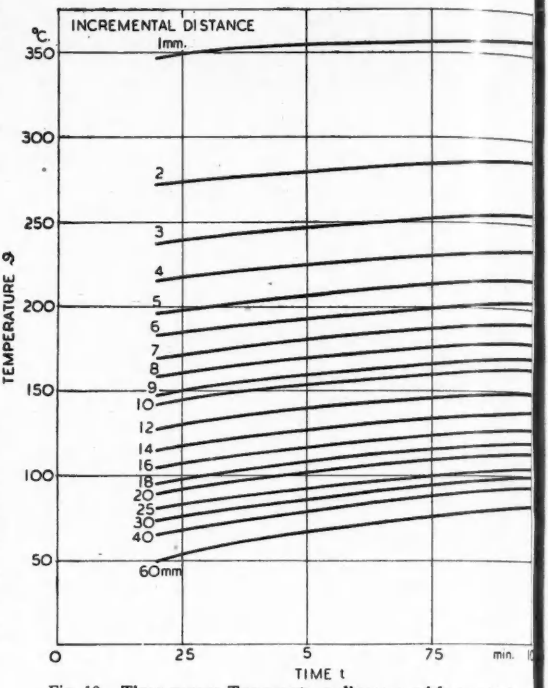


Fig. 10. **Time versus Temperature diagram with constant distance curves.** Derived from Fig. 9.

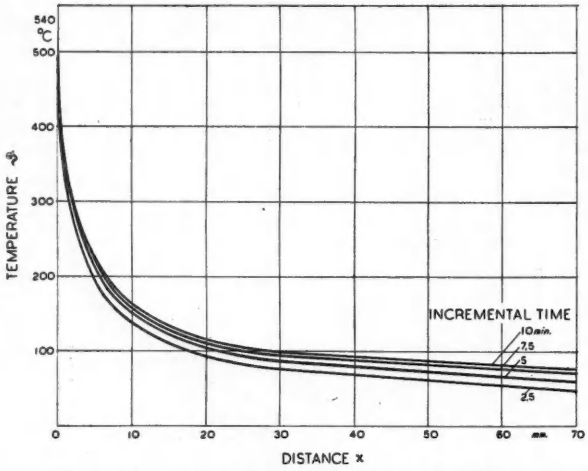


Fig. 9. **Distance versus Temperature diagram for different time increments.** Derived from Fig. 8.

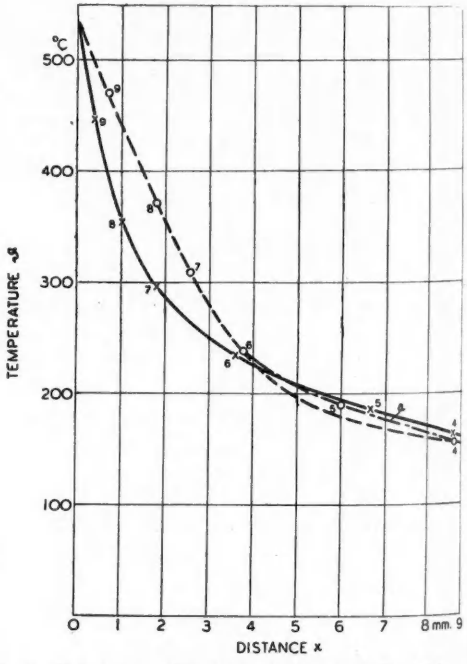


Fig. 11. **Temperature distribution in the proximity of the cutting edge after 5 min. cutting time.**
o According to Schallbroch and Lang.
x According to the incremental method.

was a.s = 3.25 x 0.48 sq. mm. No cutting fluid was used. The cutting force was measured as P_H = 212 kg. The energy input during the cutting period of 16 minutes is found as

$$A = \frac{P_H \cdot v \cdot t}{427} = \frac{212 \cdot 20 \cdot 16}{427} = 159 \text{ kcal.}$$

The heat absorbed by the tool was ascertained by measuring the temperature increase of a given quantity of water in which the tool was immersed upon completion of the cutting process. In this way the heat absorption of the tool after 16 minutes of operation was found as 1.79 kcal. This is to say, that no more than 1 per cent of the heat input during the cutting time was absorbed by the tool. This observation agrees well with comparable measurements of other workers.

The heat absorbed by the tool can be charted in a diagram analogous to Fig. 9 if the metal volumina co-ordinated with the distance increments are known. By way of approximation the incremented volumina will be represented by a number of slices as shown in Fig. 12a. If the individual volumina of these slices are multiplied by the respective average temperature elevations above 20 deg. C. (Fig. 12b), and also by the specific heat of the steel, Fig. 12c is obtained which shows the respective amounts of heat absorbed by the incremental slices at the end of 10 min. cutting time. The total heat absorption is then easily obtained by totalling up the individual amounts.

This graphic representation furnishes evidence of the smallness of heat absorption by the tool, and it also proves that a recent proposal to increase the heat removal by attaching a good heat conducting piece of light alloy to the tool cannot possibly serve any useful purpose. Equally useless were proposals made some 30 years ago to increase heat removal by internal cooling of the tool.

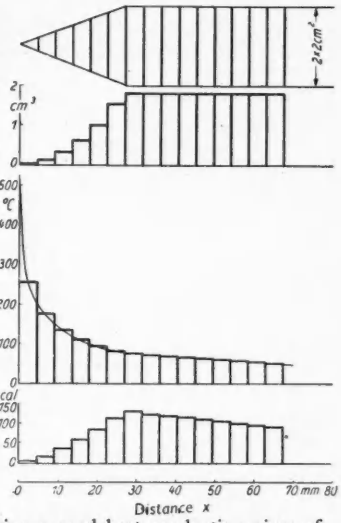


Fig. 12. Determination of the heat absorption of a cutting tool by sectionalisation and determination of the heat absorption of the individual sections.

(a) Volume determination.

(b) Mean temperature rise of sections.

(c) Mean heat absorption of sections.

OPERATING ECONOMY of PNEUMATIC & STEAM FORGING HAMMERS

By F KNORR. (From *Stahl und Eisen*, Vol. 63, No. 23, June 10th, 1943, pp. 456-462).

(*Continued from our previous issue*).

ALTHOUGH steam hammers are employed for a great many purposes, the many factors which are decisive upon operating economy have not been mentioned in the literature extant.

For automatically operating hammers of up to 2,000 kg., slide valves are still employed; while manually controlled steam hammers of more than 1000 kg. hammer weight are preferably equipped with piston valves. The establishment of accurate steam consumption data meets with considerable difficulties, chiefly because of the following factors:—

(1) The variation in steam consumption with the force of the hammer blow.

(2) The irregularities in time intervals between the successive hammering sequences in the course of forging of individual pieces.

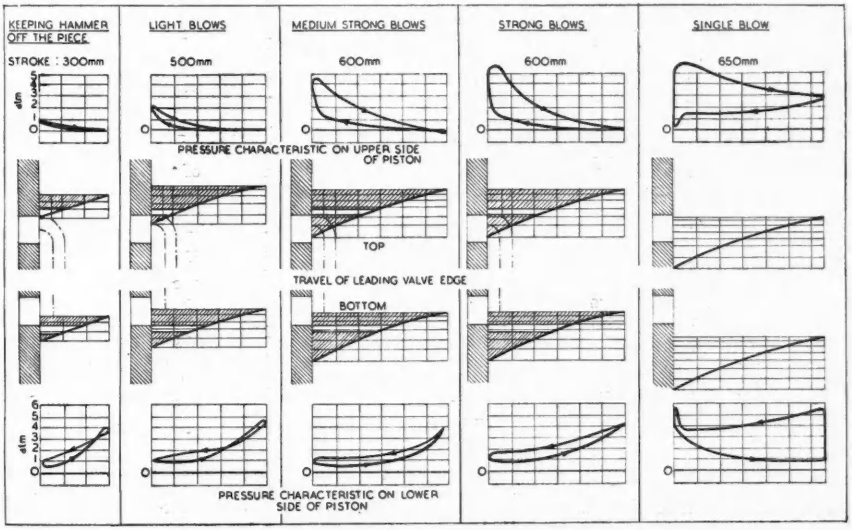


Fig. 1. Indicator diagrams of a 500 kg. steam hammer.

(3) Pressure drop and heat losses in the steam supply lines.
(4) Steam leakage caused by progressive wear of the hammer.
(5) Variations in the length of the effective stroke of the tup caused by the different heights of the pieces.

The steam consumption can be obtained with sufficient accuracy in cases where identical forging operations are carried out in series, with fairly uniform occurrence of hammering sequences, each being carried out at relatively constant strength of the hammer blow. This is not, however, the case where single pieces are forged, since such individual forging operations entail the employment of hammer blows varying both in number and strength of blow. This fact has not met with sufficient consideration when establishing steam consumption data, and such published figures are thus no more than a rough approximation of actual conditions, and so of little practical value. In order to establish the interrelationship prevailing between strength of blow and steam consumption, the indicator diagrams shown in Fig. 1 were taken.

Owing to the lack of uniformity in operation, considerable peak loads occur in shops in which a number of hammers and other steam driven machines are operated. Analogous conditions prevail in the case of pneumatic hammer installations, and in such plants the provision of large air receiver capacity is resorted to. The economy of compressed air plants can also be increased by heating the compressed air by the waste heat of the furnaces. Compared to compressed air operation, steam operation possesses the advantage of greater elasticity, but suffers from the disadvantage that disproportionately large boiler capacity must be kept in service when only one or a small number of the hammers installed are operating. The considerable length of steam piping required to supply the hammers is also a disadvantage because of the considerable heat losses incurred. These losses may amount to as much as 40-50 per cent of the steam generated. Good insulation of the steam piping is therefore important; also the boiler should be installed as near the hammer shop as possible. The warming up of the hammer, which may take one half to one hour, likewise entails a considerable steam consumption; and keeping the hammer warm during intervals between forging operations is another source of steam loss. Continuity of operation should therefore be aimed at. Losses of this kind are absent in pneumatic hammer operation.

Condensation losses in the hammer cylinder can be decreased by efficient cylinder drainage; but under the rough service conditions prevailing in hammer operation, cylinder drainage and condensation removal from pipe lines are often insufficiently attended to, with the result that losses by condensation may actually be larger than the consumption of working steam. Unduly large cylinder diameters are another source of excessive loss by condensation. While the employment of superheated steam will decrease condensation losses, it will increase the amount of work required to keep glands and piston rings tight. The progressive wear of the latter, and also of the valves, may aggravate steam losses to such an extent that—as actual operating experience has shown—no more than 25-30 per cent of the steam supplied to the hammer is utilised for actual operation.

A comparison of the operating characteristics of steam and pneumatic hammers shows that with the pneumatic hammer, the number of blows per minute remains constant irrespective of the strength of blow effected. The length of time available for turning the piece between blows therefore remains constant also, irrespective of the force of the blow. In contrast to this, increasing the strength of blow in steam hammer operation decreases the time interval between the blows and leaves less time for manipulation of the piece.

Furthermore, the pneumatic hammer enables the giving of single blows of maximum force; while with the steam hammer manually adjusted, single blows can be given which are of greater force than those effected in automatic continuous operation. With regard to the effects of setting blows, the steam hammer is also superior. There is little difference between the respective costs of upkeep incurred with the two hammers.

Data regarding the energy consumption of a pneumatic hammer and of a steam hammer, operated with either cold or preheated air, are charted in Fig. 2. Here it is seen that with decreasing strength of blow, the power consumption of the pneumatic hammer decreases less than that of the steam hammer. For a range from light blows to about 33 per cent of full force of blow, the steam hammer is therefore superior. Still more favourable conditions prevail with the use of preheated compressed air.

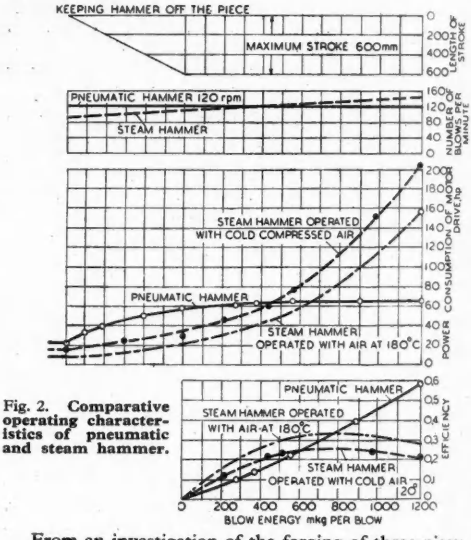

KEEPING HAMMER OFF THE PIECE
MAXIMUM STROKE 600mm
LENGTH OF STROKE
PNEUMATIC HAMMER 120 rpm
STEAM HAMMER
NUMBER OF BLOWS PER MINUTE
STEAM HAMMER OPERATED WITH COLD COMPRESSED AIR
PNEUMATIC HAMMER
STEAM HAMMER OPERATED WITH AIR AT 180°C
POWER CONSUMPTION OF MOTOR DRIVEN AIR COMPRESSOR
PNEUMATIC HAMMER
STEAM HAMMER OPERATED WITH AIR AT 180°C
STEAM HAMMER OPERATED WITH COLD AIR
EFFICIENCY
BLOW ENERGY mkg PER BLOW

Fig. 2. Comparative operating characteristics of pneumatic and steam hammer.

From an investigation of the forging of three pieces of different weight and shape, the respective power requirements of the two hammers are found as follows:—

Pneumatic hammer = 1
Steam hammer operated with cold compressed air = 1.82
Steam hammer operated with preheated compressed air = 1.285

Whether hammers of the steam or of the pneumatic type should be installed, must depend on the respective cost of the machine, as well as upon the operating medium available in the plant considered. Obviously, the longer the idling period, the more preferable is the use of a pneumatic hammer. But in this connection, it must not be overlooked that with increasing wear, the blow strength of the pneumatic hammer decreases, but the power requirements decrease hardly at all. Increasing wear of the steam hammer will not be attended by a diminution of the blow strength, but the power consumption will become larger.

With the increased use of alloy steels of greater hardness as comparable to mild carbon steel, larger hammers must be used. Where this has not been done, overloading of the hammer and excessive wear result, as actual operating records have proven. This is a point to be carefully considered in the planning of new plants; and it is recommended that hammer sizes should be correspondingly increased. If this is done, increased expenditure will soon be more than compensated for by lower upkeep costs.

THE AERODYNAMIC TURBINE versus STEAM AND GAS TURBINES

By C. KELLER. (From *Escher Wyss Mitteilungen*, Vol. 15-16, 1942-43, pp. 20-41.)

(Continued from our previous issue)

The point of respective discharge or supply from the high pressure part of the circuit is preferably located between compressor delivery and the heat exchanger inlet. In this part of the circuit, the discharged working medium possesses the final temperature of compression, and the outlet valve mechanism, therefore, is not subjected to high operating temperature. On the other hand, during admission, the working medium need not be preheated, as the thermal storage capacity of the heat exchanger suffices for adequate preheating. This also makes firing control an easy matter, since it need not be particularly quick acting.

A temporary fall in temperature does not matter, as the control gear will act to increase power output by the expedient of a slight increase in circuit pressure. Thus a temporary pressure increase of 15 per cent will suffice to compensate for a temperature drop of 50 deg. C. Additional storage capacity, therefore, is not required. The actual characteristic of the control process with unloading of the set is shown in Fig. 14. Where temporary cyclic load fluctuations are to be dealt with, output variation is preferably achieved with the use of a by-pass valve (10) (Fig. 13) rather than by varying the density of the working medium by bringing the storage system into action. Alternative use of these two control methods according to prevailing load conditions can be effected by appropriate adjustment of the control gear.

PLANT DESIGN.

The typical layout of an aerodynamic plant for a capacity of 12,000 kW is shown in Fig. 15. Here the low pressure turbine operating at 3,000 r.p.m. is coupled direct to the generator, while the high pressure unit running at higher speed solely drives the compressor. High and low pressure turbines are mechanically coupled so that small transient loads arising from the control process can be transmitted from one unit to the other, but no power transmission between the units takes place under normal conditions. Starting of the plant is effected by means of an electric motor or of a diesel.

The flexibility in plant design inherent in the aerodynamic system is also exemplified by the layout of a 36,000 kW installation, which is shown in Fig. 16. This output can be obtained with a single unit. The entire machinery including heat exchanger, pre-cooler and inter-coolers, is arranged above floor level, obviating the need for a special foundation. It is also worthy of note that where cold cooling water is available, single-shaft units of 100,000 kW capacity can be built with no more than 30 atmos. operating pressure. By adopting a circuit pressure of 50–60 atmos., which is entirely feasible, unit sizes can be further reduced. Plant layout as a whole is greatly simplified by the small amount of auxiliary machinery required. This is in favourable contrast with high pressure steam plant practice with its undeniably great requirements of auxiliary machinery and apparatus. The fact that the aerodynamic cycle dispenses with the use of water and steam as working media is another important advantage over the steam-operated plant. Moreover, by the employment of air-cooled inter-coolers, the need for water can be entirely eliminated.

In blast furnace practice, in coking plants, refineries and similar installations, large amounts of waste gas are utilised in gas engines or steam and power generation. Where waste steam is also available, the use of mixed pressure turbines must necessarily further complicate operation and increase space requirements. In order to make these gases available for the operation of gas turbines, they must be compressed for introduction and burning in the pressure furnace of the gas turbine set. The gases must, therefore, be cooled first, and in most cases also be cleaned, which involves considerable complications of plant. In the case of the aerodynamic turbine, however, neither cleaning, cooling, nor compressing of the gas is required, as the gas can be used in its hot and dirty state for the firing of the air pre-heater, thus still further increasing thermal efficiency.

The aerodynamic turbine operated with blast furnace gas can be used for the direct drive of blast furnace blowers. Since the latter require to be operated with highly variable speed and output, it may be found preferable to subdivide the turbine into a high and a low pressure plant, one driving the blower, and the other the compressor of the aerodynamic set. This makes it possible to obtain high operating efficiency, as the high pressure turbine-compressor set can thus be operated at constant speed, whilst the low pressure turbine driving the blower is speed controlled in accordance with the required blower output. Where coal is used as fuel, it may—according to the type of coal fired—be found advantageous to instal a gas producer, so that the air heater is fired with gaseous fuel. This completely eliminates the need for cleaning the gas to be fired.

The only points of the system from which heat must be rejected are the pre-cooler and the inter-cooler of the

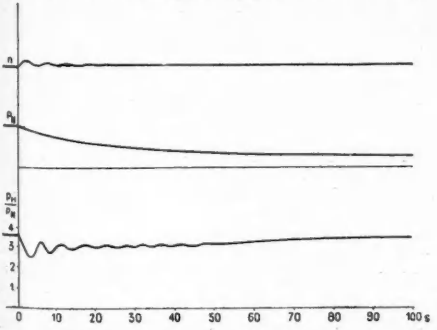


Fig. 14. **Tripping test of aerodynamic turbine.**

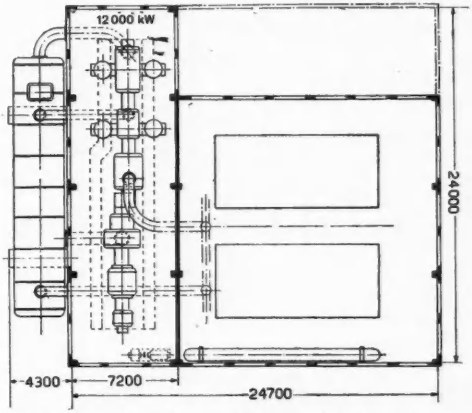


Fig. 15. **Aerodynamic power plant of 12,000 kW capacity.**

compressor. In contrast with the operating conditions prevailing in the case of the condenser of the steam cycle, a large increase in the water temperature at the aforementioned coolers is not objectionable, but this means that the cooling water requirements of the aerodynamic unit are reduced to 10–20 per cent of those of the steam cycle.

Also, the leaving temperature of the feedwater can be raised to 70–80 deg. C. without affecting cycle temperatures. This permits the use of the rejected cooling water for heating purposes, or for the supply of hot water in general (Fig. 17). Where higher water temperatures are required, these can be obtained by decreasing the regenerative effect of the cycle.

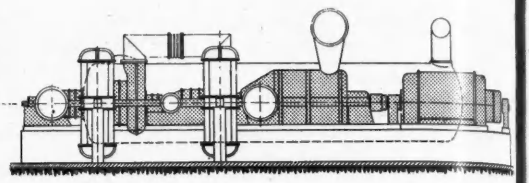


Fig. 16. **Single-flow arrangement of aerodynamic turbine.**

(Top)

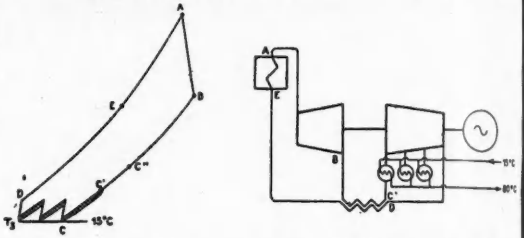


Fig. 17. **Aerodynamic turbine supplying hot water heating system.**

(Bottom)

RECENT DEVELOPMENTS OF THE ESCHER WYSS STEAM TURBINE

By F. FLATT. (From *Escher Wyss Mitteilungen*, Vol. 15-16, 1942-43, pp. 54-89.)

MULTI-STAGE turbines of the impulse type possess several important advantages over reaction type turbines, such as the permissibility of larger stage clearances, smaller number of stages, and omission of a dummy piston. As these characteristics are conducive to highest service reliability, Escher Wyss have adhered to the impulse type, and this, in spite of the fact that hydraulic losses in a curved passage tend to decrease in the presence of steam expansion. By systematic research, impulse blade contours have been developed which yield blade efficiencies nearly equal to those obtaining with reaction blading. But in most cases the slight superiority of the reaction blading is more than cancelled out by the absence of clearance losses with the impulse blading.

Exact knowledge of all secondary losses in the turbine stages such as windage losses, influence of the blade length upon efficiency, etc., is of paramount importance upon further progress in turbine design; and in this respect numerous model tests conducted with air as flow medium have contributed much useful data. In the case of large blade lengths, particular attention has been devoted to ascertain the influence of the radially increasing peripheral velocity upon the velocity diagrams. Concerning the very long blades employed in the low-pressure stages, the centrifugal forces must also be taken into account. It is, therefore, by no means a simple task to design a blade which combines maximum strength with a minimum of losses. Investigations made by Escher Wyss have shown that in the case of very large blades, as, for instance, those employed in the last stages of single-flow condensing units of 30,000–40,000 kW, a reaction effect increasing from blade root to blade top should be employed.

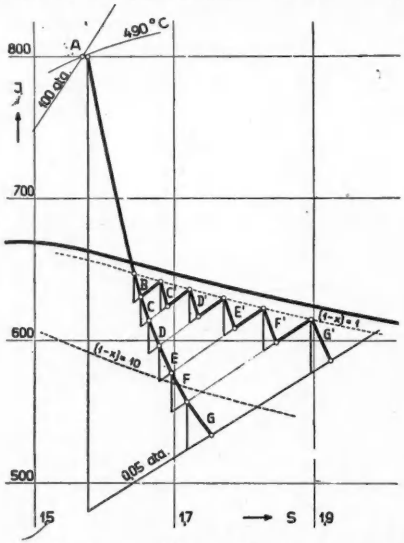


Fig. 1. **Enthalpy-Entropy diagram of a steam turbine with efficient stage moisture removal.**

While such an effect has always been provided in the last stage of impulse turbines, determination of the desirable variation in this effect in radial direction has only been achieved by recent research. In this connection it is also to be noted that the exit-energy of the last stage is largely lost in the turbine exhaust; and this, in spite of the fact that the design of the turbine exhaust is based on the results of aerodynamic model tests with a view to effecting partial recovery of the exhaust energy by a diffuser effect.

In the operation with wet steam, low pressure impulse turbines have proved superior to the reaction type, since the impulse blading is less susceptible to erosion. This is attributed to the fact that the greater curvature of the impulse blade provides a better separating effect. Fundamentally, each individual turbine stage can be considered as a double effect centrifuge, combining, as it does, deflection in the passage between the blades with the centrifugal action due to rotation. If dimensions are properly chosen, this separating effect can be utilised for the removal of water from the steam by directing it into specially provided circumferential grooves in the casing, from whence it can be drained away to the condenser or to a heater stage. In this way a low moisture content at the inlet of the subsequent stage is obtained, and passage of large water droplets from one stage to another is prevented. Thus, each row of buckets is subjected only to the action of the moisture formed in the stage itself. Moreover, as the time of passage of the steam through the nozzles is very small, the formation of large droplets prior to admission of the steam to the bucket cannot occur. This explains why the buckets of Escher Wyss turbines do not show any traces of harmful erosions after as much as 20,000–30,000 hours of service.

Owing to the effective moisture removal achieved in the low pressure part of Escher Wyss turbines, the diagram of expansion does not lie along the usual expansion line (the region of wet steam A, B, C, D-G, Fig. 1), but the stage expansions (proceeding from a certain initial wetness, as, e.g., 1 per cent) proceed along the lines A-B, C^1-D^1-E^1-F^1-G^1. Therefore it is immaterial whether the theoretical steam wetness of the last stage amounts to 10 per cent or 15 per cent.; and Escher Wyss turbines can thus be built to expand high pressure steam of, e.g., 100 atmos. and 490 deg.C. down to vacuum without requiring interstage reheating.

Scientific investigation of the phenomena which accompany the warming-up of a turbine, and particularly measurements conducted on artificially heated models of flanges and turbine casings, have pointed the way to more suitable designs. An outstanding feature of these is the use of broad and high flanges with the bolts located as closely as possible to the inner wall of the lower half of the casing. This results in small bolt and flange stresses, while at the same time the additional heat stresses prevailing during the starting-up period are kept within tolerable limits, as the screwed-in steel bolts are quickly heated because of the good thermal conduction in the threaded part. If ordinary bolting were employed, the poor heat conduction from the casing to the contacting surfaces of bolt head and nut would lead to the setting up of considerably larger temperature differences between flange and bolt. The casing flange of a 100 atmos. turbine is shown in Fig. 2, and note should be taken of the slightly conical and uniform shape of the casing, which secures a uniform distribution of bolt stresses, besides making possible accurate computation of stresses. Actual extensometer measurements (conducted with a Huggenberger Tensometer) served as a check of computed casing stresses, while special extensometers were used to ascertain bolt stresses, as can be seen in Fig. 3.

The high degree of superheat mostly employed in conjunction with high pressure steam is the cause of considerable thermal expansion. In view of the large blade clearances permissible with impulse turbines, even large expansion movements both in radial and axial directions are of no particular import, particularly as with rapid warming-up of the turbine, the rotor comes up to temperature more rapidly than the casing. It is usual practice to bolt only the low pressure end of the casing to the turbine foundation, so that both casing and turbine shaft can freely expand towards the high pressure end of the turbine; while the high pressure end of the turbine is bolted to the casing in order to obviate changes in axial clearance between the nozzles and buckets. Experiments have shown that easy sliding of the high pressure bearing pedestal is most important, especially so, as it carries a large portion of the weight of the casing. Escher Wyss turbines are, therefore, equipped with a rolling support which facilitates sliding of the bearing. This is particularly important in cases where the shafts of a two-casing turbine unit are rigidly coupled, which may cause the extreme high-pressure end bearing to move from 12–14 mm. in an axial direction.

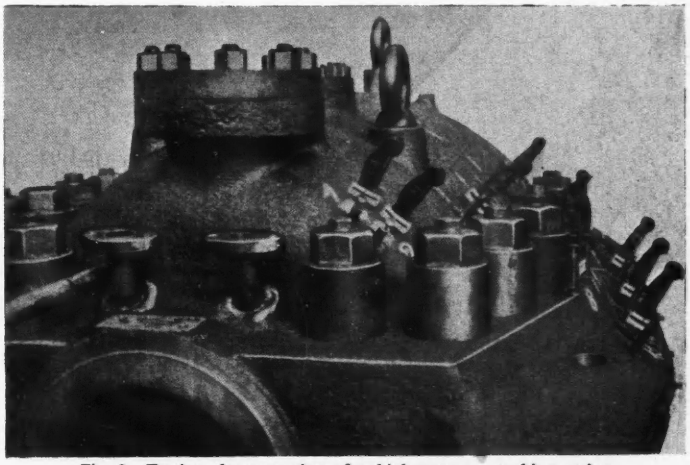


Fig. 3. **Testing the expansion of a high pressure turbine casing.**

The labyrinth glands of Escher Wyss turbines are made with fixed carbon rings which prevent the creation of torsional shaft vibrations and attendant oscillations of the buckets, should occasional rubbing occur. This feature permits the use of very small clearances which reduce leakage loss between stages as well as gland leakage even at highest pressures. This measure is of particular importance in the case of high pressure turbines of small and medium capacity; and the carbon labyrinth has, therefore, considerably contributed to the economic utilisation of comparatively small steam throughputs, as, e.g., 20 tons per hour at the high pressure of 100 atmos. Furthermore, the carbon labyrinth permits the employment of high pressures subsequent to the first turbine stage, so that a smaller first-stage drop than usual can be used. A remarkable example of the application of the carbon labyrinth gland is given in Fig. 4, which refers to a special turbine design for the fan-drive of a high-pressure boiler. This gland is subjected to a steam condition of 100 atmos. at 485 deg. C. as a total steam quantity of 150 tons per hour is expanded in this unit from

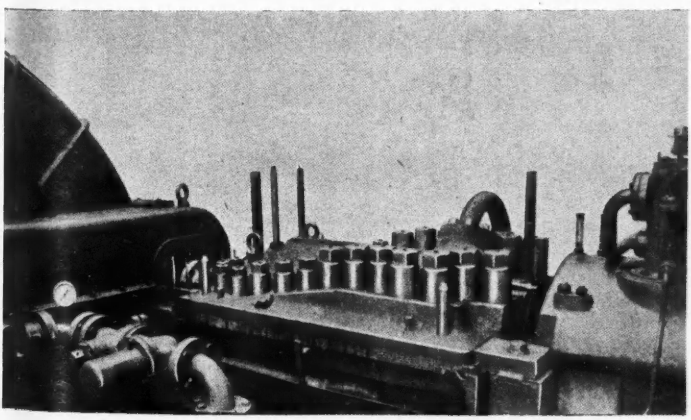


Fig. 2. **Horizontally divided casing of modern 100 atmos. turbine.**

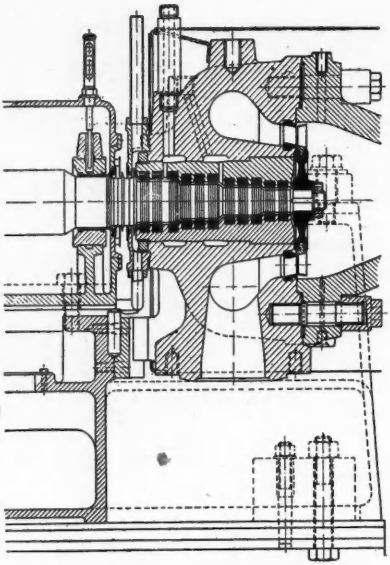


Fig. 4. **Special turbine type for driving the induced draught fans of high pressure boilers.**

105 down to 100 atmos. prior to its admission to the main turbine.

As an increase in operating pressure beyond 100–120 atmos. does not offer any considerable improvement in thermal economy, the problem of increased final steam temperature becomes an important question. In order to make possible the employment of 600 deg. C. steam temperature at the high pressure of 100 atmos., the high pressure casing of the turbine can be protected by the patented Escher Wyss design, in which an insulating layer is placed between the stationary blading and the inside wall of the casing. Where necessary, the insulation can be cooled by a system of cooling coils as shown in Fig. 5. If this system is employed, it

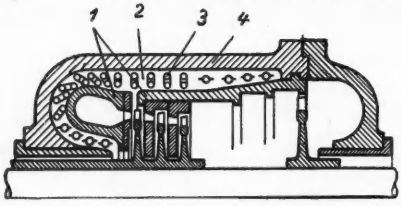


Fig. 5. **Internally cooled casing of a turbine to operate with 600 deg. C. steam at highest pressures.**

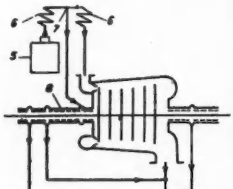


Fig. 6. **Protection of the gland of a 600 deg. C. turbine by the admission of moderately superheated steam.**

(1) Internal casing. (2) Cooling space. (3) Cooling coils. (4) External casing. (5) Steam boiler. (6) Superheater. (7) Withdrawal of moderate temperature steam. (8) Gland.

will even be possible to use an ordinary steel casting for the casing. According to another patented Escher Wyss design, the high pressure gland can be protected against excessive temperature by injecting steam of low superheat, as outlined in Fig. 6. No cooling of the buckets will be required, as they are short and rotate at moderate peripheral speed.

CENTRAL STATION TURBINES.*

It is not easy to determine the maximum output which can be economically produced by a turbine set for which the dimensions of the last stage are fixed; and it will be seen below that this question possesses validity only if the possibility of vacuum utilisation is taken into account.

If a given turbine is made to operate with an increased vacuum, the adiabatic heat drop available is

* H. Bollier and T. T. Spoerry, *Escher Wyss Mitt*, 1942-43, p. 62.

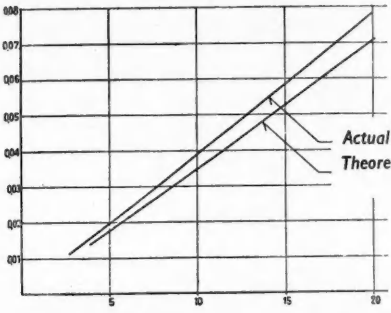


Fig. 7. **Theoretical versus actual limiting vacuum.**

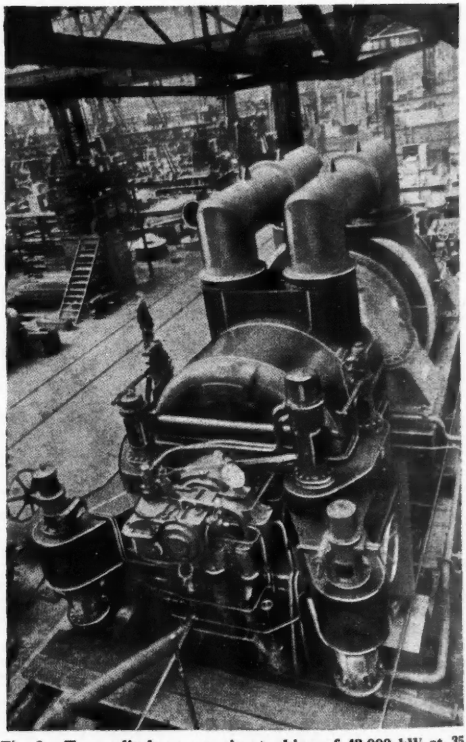


Fig. 8. **Two-cylinder max. size turbine of 42,000 kW at 35 atmos. g. designed for eventual addition of a high pressure part of 90 atmos. g.**

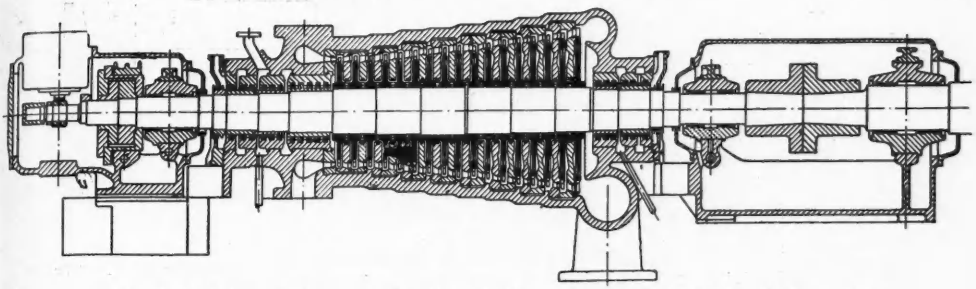


Fig. 9. **Rigidly coupled superposed turbine for 95 atmos. at 490 deg. C. of 15,000 kW capacity.**

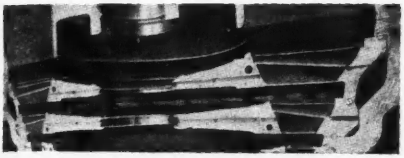


Fig. 10. **Moisture removal device of Escher Wyss turbine.**

" turbine limit capacity " is usually taken to define the maximum size to which a turbine can be built in consideration of the permissible diameter of the last stage, this concept should be rather defined as the economic limit capacity which must not be exceeded from the aspect of optimum operating economy. This economic limit capacity must, of course, be established in consideration of operating conditions such as most frequent

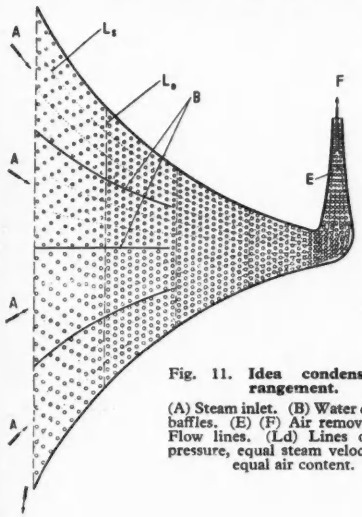


Fig. 11. **Idea condenser arrangement.**

(A) Steam inlet. (B) Water deflector baffles. (E) (F) Air removal. (Ls) Flow lines. (Ld) Lines of equal pressure, equal steam velocity, and equal air content.

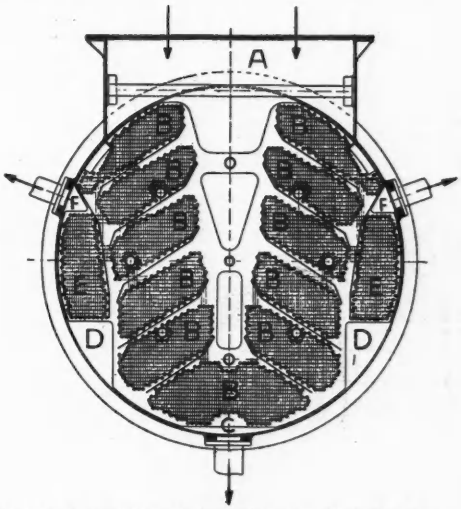


Fig. 12. **Escher Wyss condenser based on the features of ideal condenser (Fig. 11).**

correspondingly increased, but at the same time the increased steam volume leads to an increased exhaust velocity, and with it an increased exhaust loss. If the vacuum is progressively increased, a point will finally be reached at which the increase in heat drop equals the increase in exhaust loss, so that any further improvement in vacuum will bring no gain. This is the usual definition of limiting vacuum, which, as Fig. 7 shows, is different from the actual limiting vacuum arrived at by considering also turbine losses proper incurred in utilising the additional heat drop available because of the increase in vacuum. Thus, whilst in itself the often used term

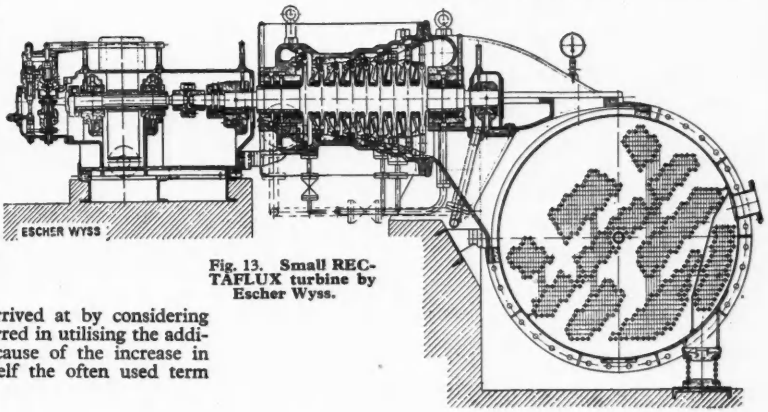


Fig. 13. **Small RECTAFLUX turbine by Escher Wyss.**

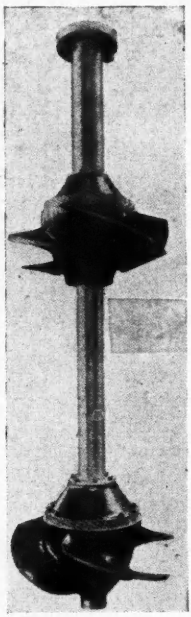
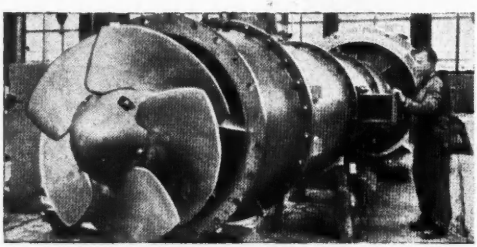


Fig. 14. **Vertical circulating pump with adjustable impellers.**

load condition, utilisation factor, peak load duration, etc. A double flow two-cylinder limit capacity turbine of a capacity of 42,000 kW at 35 atmos. pressure is shown in Fig. 8. This unit is so designed that it can eventually be operated in conjunction with a superposed high pressure part admitting steam at 90 atmos. with a total output of 50,000 kW. Another high pressure superposed unit of this type for 95 atmos. admission pressure and 490 deg. C. live steam temperature to deliver 15,000 kW is illustrated in Fig. 9. It should be noted that this is a direct rigidly coupled unit to revolve at 3,000 r.p.m.

With the system of interstage moisture removal, already referred to above and illustrated in Fig. 10, the live steam temperature need not be higher than 400 deg. C. at 55 atmos. abs. or 485 deg. C. at 100 atmos. abs. to secure satisfactory moisture at the exhaust without interstage superheating.



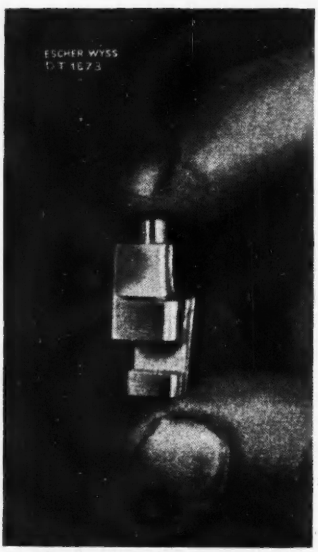


Fig. 15. **Smallest high pressure bucket (actual size).**

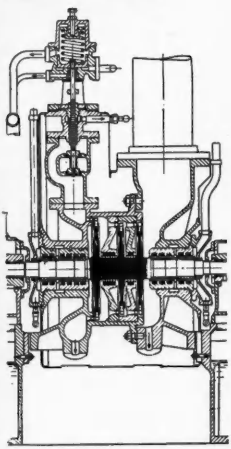


Fig. 17. **Three-stage turbine for high efficiency with moderate heat drop.**

Fig. 18. **Centrifugal compressor of 6,700 h.p. driven by condensing turbine.**

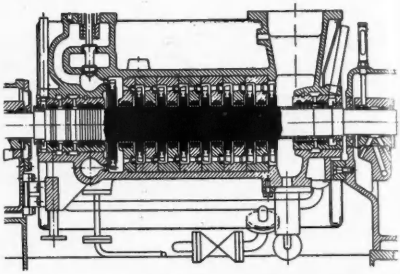
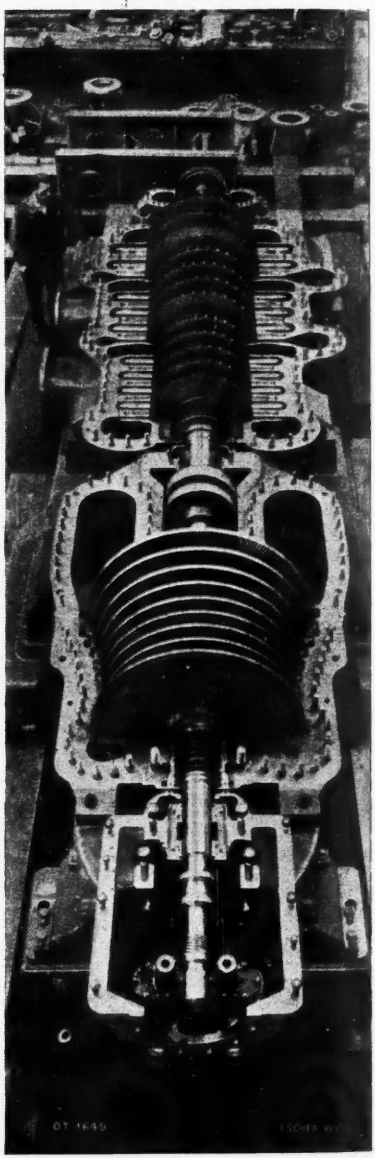


Fig. 16. **Multi-stage turbine for large heat drop with small steam flow.**



An ideal condenser with optimum operating characteristics would have to be of the shape outlined in Fig. 11, but it is obvious that considerable modifications are required to arrive at a practicable design. An Escher Wyss condenser evolved from the ideal condenser is illustrated in Fig. 12. The same principle is retained in simplified form in the condenser of the small unit shown in Fig. 13. The vertical circulating water pump illustrated in Fig. 14 is of the adjustable impeller type, combining small space requirements with good efficiency at fractional loads.

INDUSTRIAL TURBINES. *

In contrast with the large turbines required for central station service, industrial turbines are as a rule comparatively small units built to deliver process steam and often also to drive turbo-compressors and other machines at varying speed. Both prevailing power and process steam requirements must, therefore, be considered in their design. Because of the low efficiency hitherto obtainable with small steam volumes at high pressure, the employment of high pressure steam in industrial plants was necessarily limited to large industrial works. This difficulty has now been overcome by the precision manufacture of the small steam buckets required for small industrial high pressure units (Fig. 15) their design being based on novel methods of aerodynamic research. It is therefore now possible to build Escher Wyss high pressure turbines for 100 atmos. pressure for outputs as small as 1,000 kW, the thermodynamic efficiency approximating to 70 per cent, including the reduction gearing. The use of geared turbines for small throughputs of high pressure steam is motivated by the fact that it leads to larger blades with consequently higher efficiency. Moreover, the use of larger blading for a given steam quantity calls for the employment of relatively smaller wheel diameters, which, in turn, serves to reduce wheel friction and leakage losses etc. Also, small units can be started more rapidly than large ones and thermal expansion is likewise reduced. An industrial multi-stage unit designed for a small volume of steam in conjunction with a high heat drop is shown in Fig. 16, while a three-stage turbine for high efficiency with moderate heat drop is illustrated in Fig. 17. Finally, a condensing unit direct coupled with a centrifugal compressor is shown in Fig. 18 with the upper halves of the casing removed.

TURBINE GOVERNORS.†

For the combined speed and pressure control of by-product power turbines for process steam supply, a special compound governor is employed. This type of control gear is tested by special methods as illustrated in Fig. 19. In this set-up, speed control action of the servo-motor is studied by impressing various kinds of speed variations of different frequencies and simultaneously recording the movement of the piston rod of the servo-motor.

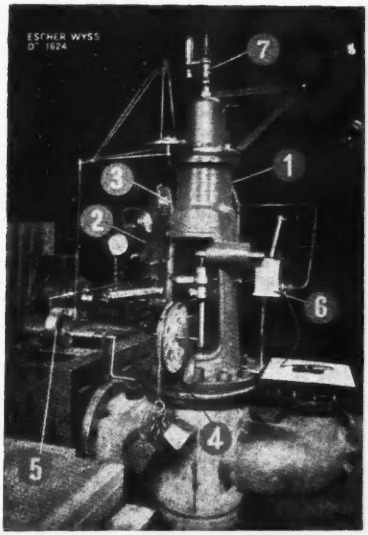


Fig. 19. **Escher Wyss turbine governor on the test bench.**

For the sake of satisfactory operating characteristics, small turbines should be equipped with governors of low inertia. This requirement has been met by the development of high-speed governors with small fly weights, the governor being housed in a casing of relatively small size. For the purpose of process pressure control, regulators of the jet deflection type have been developed, which can also be used for the combined control of pressure and quantity, the resultant impulse being mechanically transmitted to the controlled organ.

* R. W. Peter, *Escher Wyss Mitt.*, 1942-43, p. 75.
† A. Luthi, *Escher Wyss Mitt.*, 1942-43, p. 84.

IMPORTANCE OF PROPER CHOICE OF HEAT EXCHANGER SURFACE, PARTICULARLY IN POWER PLANT EQUIPMENT.

By K. Jaroschek. (From *Zeitschrift des VDI*, Vol. 87, No. 15-16, April 17th, 1943, pp. 210-213.)

The influence of the amount of heat to be transmitted Q (kcal per hour per deg. C.) and of the heat transmission coefficient K (kcal per sq. metres per deg. C.), as well as of the temperature difference Δt (deg. C.) between the heat exchanging media, upon the surface F (sq. metres) is given by the simple equation $F = Q/K\,\Delta t$; while the heat transmission coefficient must be obtained in the usual manner as the resultant of the heat transfer coefficients α_a and α_i on the respective wall surfaces, of the heat conductivity λ of the tube wall, and of inside and outside tube diameter.

HEAT TRANSMISSION COEFFICIENTS OF HEAT EXCHANGERS.

Clean Surfaces.—For the computation of the heat transmission coefficients obtaining with turbulent flow through a tube, the Nusselt equation $Nu = C\,Re^n\,Pr^m \left(\frac{L}{d}\right)^r$ is preferably employed. In this equation Nu, Re, and Pr, are the Nusselt, Reynolds, and Prandtl numbers respectively, while d and L are the tube diameter and length respectively, and C is a constant. For practical application to the flow of liquids, Kraussold's equation is especially suitable, which reads: $Nu = 0.024\,Re^{0.8}\,Pr^{0.37}$ for heating and $Nu = 0.024\,Re^{0.8}\,Pr^{0.3}$ for cooling.

With regard to the evaporation process, three cases must be distinguished, to wit:—(a) the case of very small heating surfaces, with free convection being predominant, (b) the ordinary boiling process in which the agitating action of the steam bubbles is the decisive factor, and (c) the heat transfer with very large temperature differences exhibiting the formation of a continuous film of steam which, similar to Leidenfrost's phenomenon, causes a diminution of the heat transfer coefficient. No generally valid equation for evaporation exists, and given cases and operating ranges are formulated on the basis of the expression $a = C\,q^n$.

Dirty Surfaces.—Only in the rarest cases is it permissible to base heat transfer coefficients on the

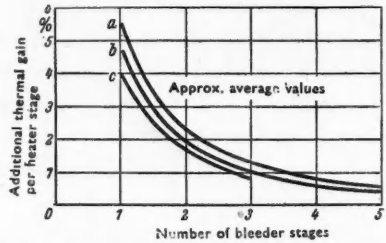


Fig. 1. **Additional thermal gain per heater stage in large steam power plant with optimum feed temperature distribution.**

assumption of clean heating surfaces. Even where chemically treated feedwater is used, a certain degree of surface dirtiness must be reckoned with in the case of plants where greatest care in the operation of the water treat-plant cannot be expected. Even forced flow does not eliminate tube wall incrustation altogether, as the molecular forces of attraction prevailing in the process of deposition exceed any such forces of inertia as may be present. To what extent incrustation must be taken into account can only be judged on the basis of actual experience.

If in the dimensioning of heat exchanger surface, no consideration has been paid to the progressive dirtying-up of heating surfaces, the amount of heat transferred between the liquids will decrease in time, and this will result in a corresponding heat loss because of the increased exit temperature of the hotter liquid; while in cases where the final temperature of the heated liquid is to be kept constant, as, for instance, in steam transformers and evaporators, it will be necessary to increase the mean temperature difference Δ t. This will, of course, also lead to thermal losses, which will often be manifested in an indirect way. There are several ways in which the deterioration in heat transmission can be counteracted. Thus, for instance, a diminution of Q may be accepted as unavoidable, or measures may be taken to increase Δ t or to instal in the first instance a heat exchanger with a larger surface F. Which road should be taken will have to be decided on the basis of economic considerations. An increase in Δ t will involve increased steam consumption and operating cost; while an increase in F will be attended by a larger initial outlay and capital charges.

Considering the smallest of steam plants with steam engines of up to 150 h.p., engine exhaust is usually employed for feed water heating, since in such small plants condensing operation offers no economic advantage. Apart from the fact that in many cases the exhaust feedwater heater was originally planned for a smaller boiler size, more often than not no consideration has been given to the aspect of dirtying-up of the heat transmitting surfaces. Thus, the feedwater heater may actually operate with a transfer rate of only 300-600 kcal per sq. metres per deg. C. as compared to a

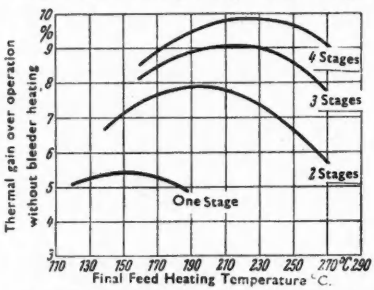


Fig. 2. **Influence of deviation from optimum feed temperatures upon thermal gain with different number of feed heater stages.**

design rate of 800-1200 kcal per sq. metres per deg. C., and a planned feedwater temperature of 90 deg. C. may never be reached again once the surfaces have become dirty. But operation with 50-70 deg. C. final feed temperature, instead of with 90 deg. C., means a 3-6 per cent loss in possible fuel savings.

Somewhat more difficult conditions exist in large plants in which two or three stage extraction feed heating is employed. Here it is the problem of the choice of the optimum number of feed heater stages which must be solved. This problem has been investigated by several workers. Among these, H. Goerke* has established the graph reproduced in Fig. 1, which shows the additional thermal savings obtainable by increasing the number of feed heating stages. Since thermal gain is counteracted by increased capital cost, the economic limit of stage increase will be set by a thermal efficiency increase of 0.5 to 1.0 per cent per stage. Also, an increased number of feed heating stages leads to a rise in boiler cost, as increased feed water temperature calls for enlargement of the air-preheater surface in order to maintain specified boiler efficiency. But H. Goerke has also shown that on economic grounds it cannot be justified to instal reserve surface in anticipation of diminished heat transfer because of the dirtying-up of the heater surfaces.

Referring to Fig. 2, it will be seen that with three stage heaters a decrease in final feed temperature by 30 deg. C. results in no more than 0.4 per cent increase in the heat consumption per kW hour. In a plant operating at 40 atmos. pressure with three-stage feed-heating to 180 deg. C., a decrease in feed temperature by 30 deg. C. because of dirty feed heater surfaces will cause an additional thermal loss of about 0.1 per cent on account of the decreased heat drop in the turbine. In practice, however, a loss of 10 deg. C. would have to be considered as unusually large. Assuming this figure, a 25,000 kW plant with 4,000-hour operational time per year, would show an increase in steam consumption of 640 tons, corresponding to an additional fuel cost of 1,600 RMk. In contrast to this, the high pressure stage feedheater of the same plant would cost some 18,000 RMk. An increase in expensive heating surface cannot therefore possibly be justified on economic grounds.

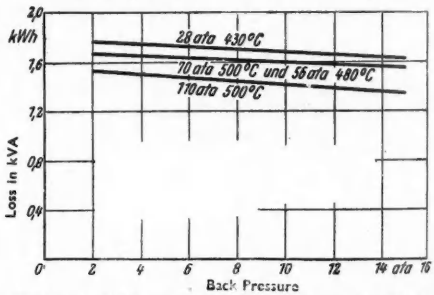


Fig. 3. **Loss in kW hr. per ton of steam and per deg. C., based on adiabatic heat drop loss in steam transformer and on 75 per cent internal turbine efficiency.**

Different conditions prevail in plants—such as chemical works—where steam transformers are used for the generation of process steam. In cases of this kind, the steam transformer surface must generally be dimensioned on the basis of a maximum temperature margin of 6-10 deg. C. between primary and process steam. Any increase in temperature margin will result in rising back pressure at the turbine exhaust, that is to say, in a decreased power output of the unit, as shown in Fig. 3. Even a small amount of scale accumulation on the transformer surface will thus lead to a decrease in available turbine capacity. The extent of the surface increase which can be justified on economic grounds

* *Archiv fur Waermewirtschaft*, Vol. 20, 1934, p.59

in a case of this kind will have to be determined from a computation of the cost that would be incurred in making up for lost back-pressure capacity by increased loading of an available condensing set or, by increased electric power purchased from a public utility system. Generally, it can be shown that in the case of a high plant utilisation factor of high outside power cost, provision of increased steam transformer surface will be well justified economically.

A GRAPHITE-ROD RESISTANCE TYPE MELTING FURNACE.

By A. KROPF. (From *Stahl und Eisen*, Vol. 64, No. 5, February 4th, 1943, pp. 94-97.)

FOR some two years a Junker graphite-rod resistance type melting furnace of 220 lb. capacity has been in experimental use in the laboratory of a German steel-making concern. This kind of electric furnace which, unlike the more usual types, employs a radiating carbon rod resistor, has only recently found its way into practice. It is said to offer considerable advantages and to be capable of producing a steel in no way inferior to crucible steel made in the ordinary way. The report refers to exhaustive operating experiences published elsewhere.* The experimental installation of the 220 lb. furnace under review here, is operated intermittently. It is mainly used in the production of high-alloy, corrosion-resistant, thin-walled castings, besides being employed for the making of experimental heats.

A 440 lb. capacity furnace of the same type is illustrated in Fig. 1, while a section of the 220 lb. capacity furnace and details of the resistor element of the latter are shown in Figs. 2 and 3. The furnace was delivered by the makers in completely assembled state. As Fig. 2 shows, there is a layer of light-weight insulation brick under the outer metal casing. Beneath the insulation brick, there is a layer of Sillimanite brick in the roof of the furnace, and a layer of fire brick in the furnace bottom. With exception of the furnace roof made of cast corundum shapes, the entire furnace lining is made with a special corundum mass beaten into place. This lining, however, lasted only through 70 heats. A second lining of corundum tamped into place by hand, lasted through 119 heats, although some repair work had become necessary after 80 heats. A third lining applied in slightly moist state and tamped down with a compressed air tool, lasted for 196 heats, repairs becoming necessary only after 165 heats. A fourth lining, which is still in use, has already withstood 246 heats.

Of the 551 heats made so far, 69.5 per cent were soft, high-alloyed Cr or Cr-Ni steels, 10 per cent were high-speed tool steels, 18.1 per cent were ordinary carbon steels, and 2.4 per cent were high-alloyed high carbon Cr steels, scraps being used as charge. The loss in alloying constituents is mainly due to the action of the slightly acid furnace lining, while the loss in carbon is caused by the oxygen of atmospheric air seeping into the furnace.

* *Stahl und Eisen*, Vol. 62, 1942, pp. 9–14.

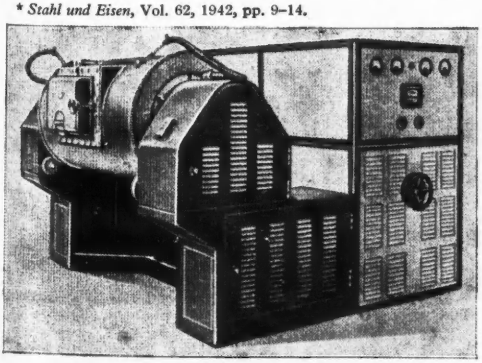


Fig. 1. View of Furnace of 440 lb. capacity.

Some of this oxygen is used up by the incandescent resistor rod. The carbon loss was found to be uniform, amounting to 0.08–0.1 per cent. In the case of Cr-steels, the manganese loss was found to approximate to 18–20 per cent, while 18 per cent Cr. corrosion-resistant steels showed a loss of approximately 4.5 per cent chromium.

The total power consumption for 551 heats including drying out and heating-up, with an average charge of 200 lb., amounted to 93,340 kWhr. Based on a total weight of charge of 49.5 metric tons, the specific power consumption is 1,880 kWhr per ton of steel. However, neglecting two initial operating periods, and basing the power consumption upon the operating period of 196 heats after the second re-lining of the furnace, the power

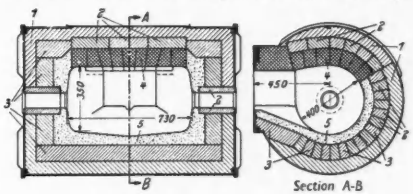
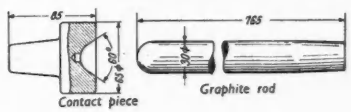


Fig. 2. Furnace Lining.
(1) Insulating brick (2) Sillimanite brick (3) Fire brick (4) Corundum brick (5) Corundum plastic lining.



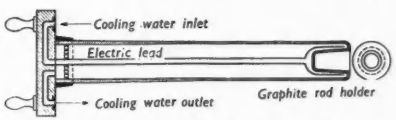


Fig. 3. Graphite Resistor and Holder.

consumption is only 1,420 kWhr per ton of charge. This figure almost equals that of an acid coreless induction furnace of 220 lb. capacity. After the lining had been renewed a third time, the power consumption further decreased to 1,255 kWhr per ton. Although these figures are somewhat higher than the power consumption rate recorded in similar installations, they are quite in line with the observations of other investigators using furnaces of the same type and capacity.

The following power consumption data are also given for the sake of comparison :—

(*a*) Basic arc furnace of 100 lb. capacity : 1,450 kWhr per ton ;
(*b*) Acid coreless induction furnace of 220 lb. capacity : 1,400 kWhr per ton ;
(*c*) Graphite-rod resistance furnace of 220 lb. capacity : 1,420–1,100 kWhr. per ton.

The report also gives a detailed list of the cost incurred in the re-lining of the furnace ; but in view of the different German price levels this is of little interest.

RELATIONSHIP BETWEEN SALT CONTENT AND CONDUCTIVITY OF BOILER WATER IN ELECTRIC BOILER OPERATION.

By A. STRUB (From *Brown-Boveri Review*, Vol. XXIX., No. 11-12, Nov.-Dec., 1942, pp. 347-352.)

IN the electrode type of boiler, alternating electric current flows between two or more electrodes under voltage through the boiler water, whereby the latter is heated or evaporated. Direct current cannot be used because hydrogen and oxygen would form at the electrodes, which, upon mixing, would constitute a dangerous explosive mixture.

Pure water is practically a non-conductor of electric current. In order that it shall become conductive, salts, bases or acids must be dissolved in it. If there is not sufficient of these present, it is possible, by the addition of compounds, to obtain the necessary conductivity for boiler operation and at the same time to prevent boiler scale. Not all molecules in an electrolyte participate in carrying the current, but only those dissociated into ions. The formation of ions depends on the nature of the dissolved substance; on its concentration in the water; on the presence of other substances, and on the temperature of the solution.

I. THE CONDUCTIVITY OF THE FEED AND BOILER WATER.

(*a*) *Method of Measurement.*

Contrary to solid substances, it is usual in the case of liquids to refer to their conductivity (κ) rather than their specific resistance (ρ), the relation being

$$\kappa = \frac{1}{\rho}$$

For exact measurements a.c. bridges are generally used.

(*b*) *Effect of dissolved substances.*

Detailed investigations have shown that part of the molecules present in a solution decompose into ions (electrolytic dissociation) and that only these ions participate in carrying the current. The percentage of molecules decomposed is called the degree of dissociation. If, for instance, ordinary salt is dissolved in water, simultaneous dissociation takes place according to the following formula :

$$\frac{NaCl}{Na'' + Cl'}$$

A singly, positively charged sodium ion (cation) and a singly, negatively charged chlorine ion (anion) form.

Between the ions and the concentration of the substance, that is, between the number of ions and of molecules contained in a solution, there hold, for example, in the case of a solution of ordinary salt :

$$k.c_s = c_i^2$$

where c_i is the concentration of the ions and c_s that of the undissociated molecules. If c is the total concentration ($c = c_i + c_s$) then it follows that

$$k = \frac{c_i^2}{c - c_i}$$

k is called the dissociation constant. If α is the degree of dissociation, that is $c_i = c.\alpha$, then it follows that

$$k = \frac{c^2.\alpha^2}{c(1-\alpha)} = \frac{c.\alpha^2}{1-\alpha}$$

With the same concentration, different substances have different conductivities, which fact is due to the ionic mobility. As shown in Fig. 2, hydrogen ions (acids) and OH ions (bases) result, because of their greater mobilities compared with metal or salt radical ions, in good conductivities. According to newer theories, the difference in the behaviour of individual electrolytic groups is due to the characteristics of the pure undissolved substances. The one group comprises all compounds which already as crystals exhibit a definite ionic lattice. The second group contains mainly either compounds which have a molecule lattice in the solid state, or those to which a unipolar has to be ascribed as waterfree substances. Only upon dissolution do such substances supply ions due, for instance, to the formation of electrolytically dissociated hydronium salts. In the first case the ions are already present in

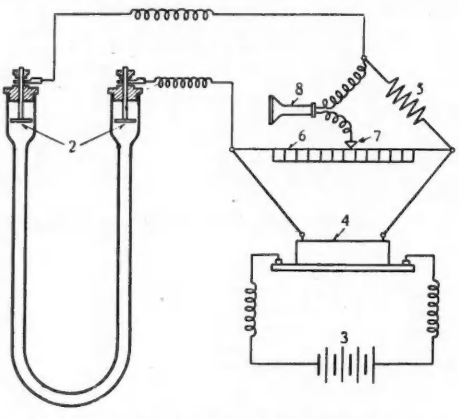


Fig. 1. **Diagram of the arrangement for measuring the specific conductivity of electrolytes**

The use of a resistance bridge in connection with an oscillator enables exact results to be obtained without precision instruments.

1. Calibrated measuring column.
2. Electrodes.
3. Battery.
4. Oscillator.
5. Resistance.
6. Bridge measuring wire.
7. Sliding contact.
8. Telephone.

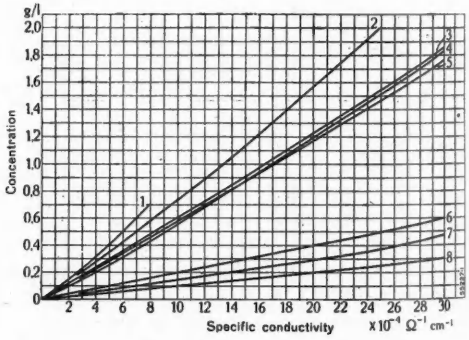


Fig. 2. **Specific conductivities of electrolytes at 18 deg. C. as function of the concentration (according to Laudolt-Börnstein)**

Up to concentrations of about 2g/litre the specific conductivity varies in an almost linear manner with the concentration

1. Ca SO_4 Calcium sulphate.
2. Na SO_4 Sodium sulphate.
3. KCl Potassium chloride.
4. Na_2 CO_3 Sodium carbonate.
5. Na Cl Sodium chloride.
6. Na OH Caustic soda.
7. H_2 SO_4 Sulphuric acid.
8. HCl Hydrochloric acid.

the undissolved substance, in the second case their formation must be preceded by a chemical reaction on the completeness of which the number of ions depends.

(c) Effect of Concentration.

The specific conductivity increases first in linear manner with increasing concentration, because the number of ions increases. At higher concentrations, the specific conductivity no longer increases proportionally, because the degree of dissociation decreases; it finally reaches a maximum and thereafter decreases. As shown in Fig. 3, this behaviour is particularly marked in the case of sulphuric acid (H_2SO_4).

(d) Effect of other substances.

If equal volumes of two solutions are mixed, the conductivity of the mixture does not correspond to the arithmetic average of the two individual values, provided the substances concerned are not practically completely dissociated, apart from the fact that, depending on the composition of the solution, chemical reactions may take place. It is therefore possible to determine the total salt content of a solution, only when a single salt is present, which is rarely the case with electric boiler water. On the other hand, conductivity measurements enable the salt content of solutions to be determined with sufficient accuracy when all the substances dissolved therein behave in a similar manner, as is the case with raw waters. Fig. 4 represents the average values of about 50 analyses with water of very different ratios of temporary to permanent hardness. The maximum departure from the curve was 10 per cent. It is often possible to make determinations of the salt content with sufficient accuracy by means of conductivity measurements when a known substance preponderates in a solution so that the conductivity is mainly determined by it.

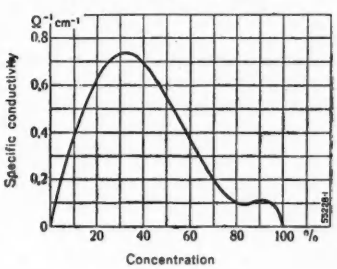


Fig. 3. **Specific conductivity of sulphuric acid (H_2SO_4) as a function**

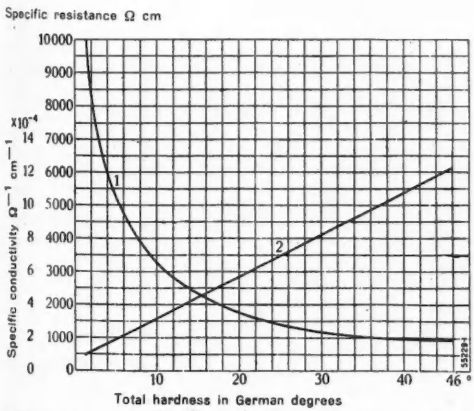


Fig. 4. **Specific resistance and conductivity of raw water at 20 deg. C. as a function of the total hardness.**
1. Specific resistance. 2. Specific conductivity.

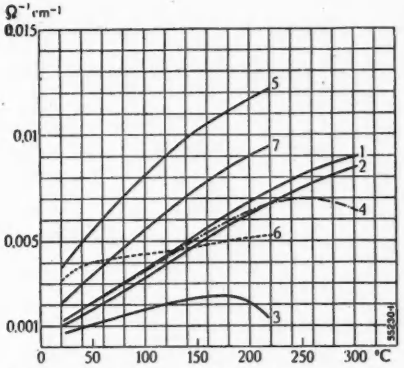


Fig. 5. **Specific electric conductivity of aqueous 0.01 normal solutions in function of the temperature**

(e) Effect of the Temperature.

The conductivity of electrolytes increases considerably with the temperature, the increase per one deg. C. being smaller at high than at low temperatures. Fig. 5 shows the variation of the conductivity with temperature for a number of normal solutions.

The relationship between conductivity and temperature is expressed by the following formula:

$$C = \frac{1}{\kappa 18^\circ} \cdot \frac{\kappa_2 - \kappa_1}{t_2 - t_1}$$

where κ_2 and κ_1 represent the conductivities at the temperatures t_2 and t_1, $\kappa 18^\circ$ the conductivity at 18 deg. C., and C the temperature coefficient. The latter amounts to 0.02 to 0.023 for weak solutions, to 0.009 to 0.016 for acids and some acid salts, and to 0.019 to 0.02 for strong bases. Allowing for the salts and bases usually dissolved in electric boiler water, a coefficient of 0.02 may be assumed with sufficient accuracy, corresponding to 2 per cent. increase of conductivity per deg. C.

II. BOILER WATER COMPOSITION AND CONDUCTIVITY.

In addition to the above-mentioned influences on the conductivity of individual dissolved substances, reference is here made to the variability of the composition of water, and the phenomena taking place during service. When a boiler is supplied with raw water of a definite hardness and conductivity, already the effect of heating and of the pressure, causes chemical reactions to take place which alter both these qualities. Bicarbonate of calcium, if present, is for instance, decomposed as follows:

$$Ca(HCO_3)_2 = CaCO_3 + CO_2 + H_2O$$

Thus, after the reaction the insoluble calcium carbonate is formed. The liberated carbonic acid escapes with the steam. The ions, necessary for carrying the current, are present only to a lesser extent, thus causing a reduction in the conductivity.

The feedwater treatment for preventing scale formation also has an important effect on the conductivity. In general, care must be taken in choosing the softening process so as to ensure that treated water shall contain as little salts or bases as possible, in order that the conductivity of the water shall not be too high, as only pure water escapes in the form of steam, thereby increasing the concentration of the remaining solution. The removal of the salts must, therefore, be effected more frequently in the case of feedwater of high conductivity. The kind of salts or bases entering into the boiler is also important. Caustic soda (Na OH) has, at the same concentration, about 3.5 times the conductivity of sodium sulphate (Na_2SO_4).

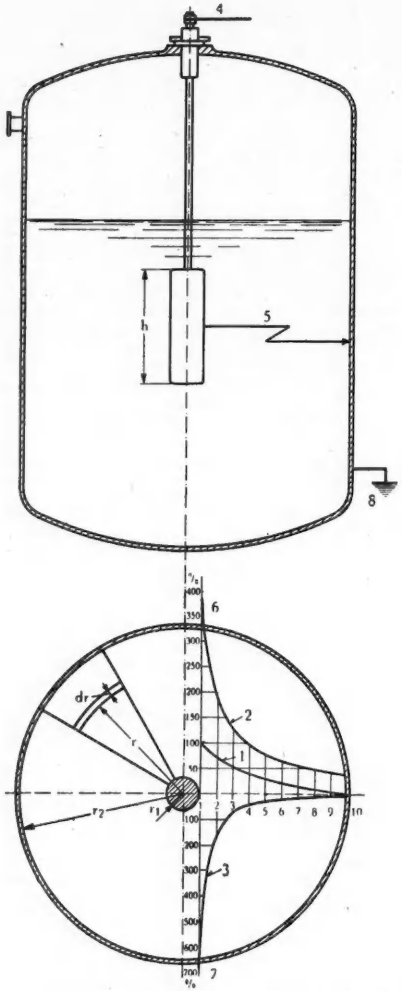


Fig. 6. Variation of the voltage and power density in a single-phase electric boiler with immersion electrode.

Curve 1. Variation of the voltage in the water between concentric electrodes.
Curve 2. Voltage loading of the water in per cent of the average voltage, loading for a radius ratio of 1:10.
Curve 3. Variation of the power density in per cent of the average density.

4. Supply. 5. Current path. 6. Voltage. 7. Power density. 8. Earth.

III. DEPENDENCE OF THE ADMISSIBLE CONDUCTIVITY OF THE WATER ON THE CONSTRUCTION OF THE BOILER.

The admissible concentration of the salts and bases in the boiler water, and hence also the maximum value of the conductivity, depends to a considerable extent on the construction and arrangement of the electrode system. If a certain maximum value is exceeded, arcing takes place. leading to unsteady operation and flash-overs. At the same time, water is decomposed and an explosive gas mixture is formed. The simplest system used for low-voltage boilers is shown in Fig. 6 as single phase. The resistance per unit length of the current path varies according to the equation

$$\frac{dR}{dr} = \frac{\rho}{2\pi h} \cdot \frac{1}{r}$$

where ρ is the specific resistance of the water. This resistance and, therefore, also the voltage drop increase rapidly near the inner electrode. The voltage per centimetre of path is

$$\frac{dV}{dr} = \frac{V}{r . \log_e \frac{r_2}{r_1}}$$

and the voltage loading of the water in percentage of the average loading

$$\frac{r_2 - r_1}{V} \cdot \frac{dV}{dr} = \frac{r_2 - r_1}{\log_e \frac{r_2}{r_1}} \cdot \frac{1}{r} \text{ (curve 2 in Fig. 6).}$$

The load density is :

$$\frac{dL}{dv} = \frac{2^2 . \rho .}{(2 . \pi . h)^2} \cdot \frac{1}{r^2}$$

It therefore varies with the square of the reciprocal of the distance from the centre of the boiler. The variation of the load density in per cent. of the average load density is :

$$\frac{V}{L} \cdot \frac{dL}{dv} = \frac{1}{2\pi \log_e \frac{r_2}{r_1}} \cdot \frac{1}{r^2} \text{ (curve 3 in Fig. 6).}$$

Thus the maximum power occurs at the surface of the electrode. The maximum steam evolution also takes place there, affecting the load distribution even more unfavourably.

Ceramic displacement bodies are built therefore into most of the boilers to reduce the cross-section of the water between the electrodes (Fig. 7). The conversion of energy mainly takes place in the reduced water sections. The main disadvantage of this system is the limited life of the ceramic bodies. Another solution is the water-jet boiler of Brown-Boveri, where the current is conducted by water jets, and the cross-section of the current flow is the same everywhere. In this case, water of higher conductivity may be used.

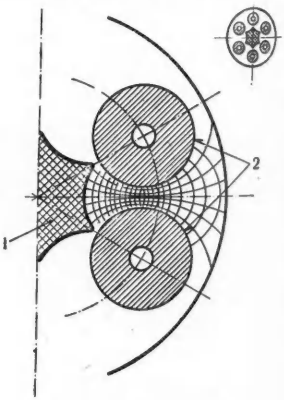


Fig. 7. Immersion electrode with displacement bodies for increasing the length of the high resistance current path

1 Electrode.
2 Displacement bodies.

TECHNICAL NEWS

Announcements in this section include News relating to British Firms, and on Equipment produced by British Manufacturers.

Available literature may be secured by addressing a request to the advertising department of "The Engineers' Digest," or by writing direct to the manufacturer and mentioning "The Engineers' Digest" as a source.

- ✦ NEW EQUIPMENT
- ✦ BOOKS AND CATALOGUES
- ✦ BUSINESS CHANGES
- ✦ PERSONAL
- ✦ NOTES

THE INSTITUTION OF MECHANICAL ENGINEERS.
Storey's Gate, St. James's Park, London, S.W.1.

FRIDAY, 21st April, at 5.30 p.m. Informal Meeting, "Planning an Aero-engine Production Programme," to be introduced by E. Fairbrother.

FRIDAY, 28th April, at 5.30 p.m. General Meeting, "The Application of Fabricated Construction to Machine Design," by F. Koenigsberger, Dipl.-Ing., A.M.I.Mech.E.

INSTITUTION OF NAVAL ARCHITECTS.
10, Upper Belgrave Street, London, S.W.1.

Meetings to be held in the Hall of the Institution of Mechanical Engineers.

WEDNESDAY, 19th April, at 2.30 p.m. Address by the President (Admiral of the Fleet the Right Hon. Lord Chatfield, G.C.B., O.M., K.C.M.G., C.V.O.); Presentation of Diploma of Honorary Membership to Professor T. H. Havelock, M.A., D.Sc., F.R.S.; Presentation of Institution Premium to Mr. J. F. C. Conn, D.Sc.; Paper No. 1. Post-War Merchant Ships from the Owners' Point of View, by W. C. Warwick; at 5 p.m. Paper No. 2. Repairs to Welded Ships, by James Turnbull.

WEDNESDAY and THURSDAY, May 10th and 11th. Papers on the application of water tube boilers to merchant ships. Further particulars will be issued at a later date.

Meetings to be held in the Library of the Royal Society of Arts:

THURSDAY, 20th April, commencing at 2.30 p.m. A Statement on the British Shipbuilding Research Association by Wilfrid Ayre; Methods of Levying Charges for Services to Shipping, by John Tutin, D.Sc.; and at 5 p.m., Comparison of Calculated and Measured Wave Resistances for a Series of Forms not Symmetrical Fore and Aft, by W. C. S. Wigley, M.A.

FRIDAY, 21st April, at 2.30 p.m. The Use of Wire Wound Electrical Resistance Strain Gauges, as applied to Engineering Problems, for the Measurement of Static Strains, by S. F. Dorey, D.Sc.; Effect of Blade Section and Area on Screw Propulsion, by G. S. Barer, O.B.E., D.Sc., and L. T. G. Clarke, B.Sc.; The Quasi-Propulsive Coefficient, by Professor E. M. Bragg, S.B.

I.A.E. MEETINGS—1944 SESSION.

THE Institution of Automobile Engineers opens its session of London General Meetings at The Royal Society of Arts, John Adam Street, Adelphi, W.C.2., on Tuesday, 4th April, at 6.15 p.m., when Mr. F. Walls, B.Sc., and Dr. J. E. Sisson, of I.C.I. Plastics Ltd., will read a paper, entitled, "Plastics in Motor Vehicles." Cards of invitation to admit visitors to this meeting may be obtained on application to the Acting Secretary, Institution of Automobile Engineers, 12, Hobart Place, London, S.W.1.

Further meetings will be held during the spring and summer months as follows:—

Tuesday, 2nd May. "Surface Finish." By Mr. W. E. R. CLAY (Rolls Royce Ltd.).

Tuesday, 6th June. "Petrol—its Development Past, Present and Future, with some Notes on the Potentialities of High-Octane Fuels for Road Vehicles." By Mr. H. FOSSETT.

Tuesday, 4th July. "The High-Speed, Two-Stroke Compression-Ignition Engine." By Mr. R. WISNER (Ricardo & Co. Ltd.).

Tuesdays, 5th September and 3rd October:—Subjects to be announced later.

All the above meetings will take place at The Royal Society of Arts at 6.15 p.m.

THE INSTITUTE OF WELDING.
2, Buckingham Palace Gardens, London, S.W.1.

12TH APRIL, at 6 p.m. Paper on "Factors controlling the Weldability of Steel," by Dr. L. Reeve.

17TH MAY, at 6 p.m. Paper on the "Welding of Plastics," by Dr. J. H. Paterson.

The Wolverhampton Production Exchange, 46a, Queen Street, Wolverhampton (Chairman Mr. A. Dyson, Manager Mr. F. D. Kilby) held its Jubilee meeting on the 22nd of February. Lord Dudley, Regional Commissioner for the Midlands, addressed the meeting and expressed the view that there will certainly be room for a permanent trade association of this kind in the difficult years that are to come. Fifty meetings were held during the first year, the aggregate attendance was 9,145, and the value of transactions £745,531. Speakers have included Sir George Schuster, M.P.; Mr. Gordon England; Sir Charles Mander; the Rt. Hon. Lord Sempil; Sir Patrick Hannon, M.P.; Mr. W. Van Helden; and Cyril D. Lloyd, M.P.

BUSINESS CHANGES.

OIL ENGINES (COVENTRY) LTD.

THE business of OIL ENGINES (COVENTRY) LIMITED, together with the sole manufacturing rights of the CUB and other horizontal diesel engines, has been purchased by Lagonda Motors Limited of Staines, whose Chairman Mr. A. P. Good is associated with several prominent companies manufacturing diesel engines.

In charge of production at Coventry is Mr. W. E. Long, General Works Manager. Mr. H. R. Scott is Commercial Manager and Mr. D. M. Milno is Sales Representative. The services of Mr. W. A. Weaver are available to the Company as Technical Consultant.

The first aim of the new company is to increase the rate of production of the famous 2-cylinder horizontal CUB diesel engines to meet the pressing requirements of the Services and Government Departments.

DUALLOYS LTD.—EXACTOR CONTROL CO. LTD.

AN amalgamation of interests has taken place between DUALLOYS Ltd. of Croydon, the well-known plain bearing manufacturers, and EXACTOR CONTROL CO. LTD. of 14, Berkeley Street, London, W.1.

Mr. J. W. Warrington, Director and General Manager of Exactor Control Company has joined the Board of Dualloys Limited and has been appointed Managing Director of the Company. Mr. Warrington was, until 1942, Chief Engineer to Messrs. The Glacier Metal Co. Ltd.

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DIAMOND TRADING COMPANY LTD.

A RESEARCH Department has recently been established by the Diamond Trading Company, Limited, whose London Office is at 32/34, Holborn Viaduct, London, E.C.

This Department is under the management of Mr. Paul Grodzinski, A.M.I.Mech.E., who is assisted by a Staff of five.

The Department is engaged in investigations into the properties of diamonds, their preparation for use and, in particular, their application in industry both present and potential.

An extensive Library and Technical Archive which has been built up over a long period of years by Mr. Grodzinski, is being continued by the Department, and its Information Service is available free of charge to all users of Diamond Tools, and any interested. Close contact is being established with other Research Bodies.

PROLONGING THE LIFE OF MECHANICAL RUBBER PARTS.

As in the case of motor tyres, great wastage of mechanical rubber parts occurs through the phenomenon of rubber, under pressure, bonding itself to its metal contacts. Thus, during dismantling operations, destructive force invariably needs to be applied to the rubber parts.

Since 1939 the majority of Commercial Motor Vehicle fleet operators have completely overcome the tyre adhesion and bead rot problem by simply coating rims before tyres are fitted with a Patent graphited product called "Tyreprim" (Regd.). Its use enables tyres to "come away" unscathed, almost as easily as they were fitted—thus effecting an enormous saving of both tyres and hard labour.

The product, therefore, has extensive uses in mechanical engineering where adhesion difficulty occurs with rubber hose connections, gaskets, rings, washers, couplings, etc.

Where rubber parts such as buffers are exposed to splashes of oil or other damaging products, a coating of Tyreprim is an effective insulation, for it repels mineral oil and is a first class rust preventive.

Additional properties of Tyreprim are: Its opacity shuts out sunlight (which perishes rubber); It reduces heat transference, has very low inflamability, tenacious adhering property and does not "dry."

PLANS FOR THE POST-WAR MARKETING OF TIN.

THE major problem facing the industry is to build up an organisation which will create a market sufficiently wide to maintain production at a reasonable level. This requires a consumption approaching 250,000 tons of tin annually. In financial terms, the pre-war market for say £30,000,000 per annum has to be re-established, and over and above this an additional market for upwards of £20,000,000 worth of new tin annually has to be discovered and developed.

This is the key note of a recently published report describing a plan worked out by Mr. John Ireland, Director of the Tin Research Institute. It is shown that sales depend on the satisfaction of the ultimate consumer and that where better service can be given, expanded consumption follows.

The proposed scheme will harness to the problem of increasing the usefulness of tin, the full resourses of a modern scientific organisation. This will comprise a nucleus of scientists whose fundamental work will be carried to the stage of practical application by research teams working on a semi-industrial scale under the guidance of committees representing each of the principal tin consuming industries.

An important feature is the establishment of Information Bureaux in all the important tin consuming centres throughout the world. These Bureaux will be staffed by practical experts ready to go into Works and put any tin consuming process into first class working order in the light of the most recent scientific knowledge. The experience gained in giving this type of service in Gt. Britain, and on a smaller scale in the U.S.A., has proved that there is a wide-spread need for it even in these areas where manufacturing technique is highly developed; and in other consuming countries there is even greater scope.

The Report explains the proposed post-war organisation in detail, and summarises the technical developments already made in all the main fields of consumption. It gives the technical grounds on which are based the reasons for expecting to restore those uses of tin abandoned or curtailed during the present scarcity. The Report also indicates some promising new uses arising out of the Institute's researches, and gives quantitative estimates of the increased sales that may be expected as the result of the new organisation's activities at the end of a ten-year period.

The budget recommended for these activities is £300,000 per annum, to cover research, development, world-wide technical service, and full-supporting publicity. This sum, although much larger than that with which the present organisation has been working, is much less than is devoted to other metals, and is only about one per cent of the gross value of the tin sold annually before the war.

ESTABLISHED LIGHT ENGINEERING FIRM, Specialised Product, Post War Prospects, FOR SALE, Limited Company. Price £3,000. Apply BEDELL & BLAIR, 44, Brazennose Street, Manchester, 2.

The day will dawn

when inclinations and resources, now diverted to war-time needs, must turn to peaceful outlets. We should like to discuss proposals from members of any industry wishing to call upon the resources of modern plant allied to extensive manufacturing experience in skilled engineering. The application of hydraulics and pneumatics for the post-war world is of particular interest to this Company.

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MANUFACTURING COMPANY LIMITED
WOLVERHAMPTON.

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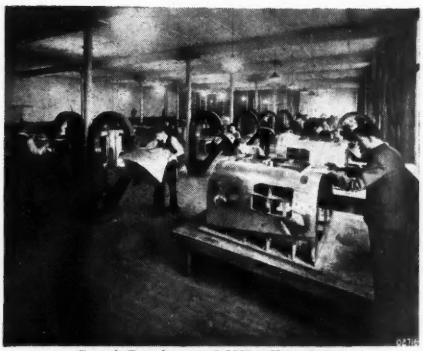

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PERSONAL.

Mr. W. G. Ardley, managing director of George Kent Ltd., has been elected chairman of the British Industrial Measuring and Control Apparatus Manufacturers' Association with offices at 21, Tothill Street, London, S.W.1.

Dr. Leo Hendrik Baekeland, inventor of bakelite plastics, who was, in 1905, Vice-president of the Society of Chemical Industry in London, died in New York at the age of 80.

Sir George E. Bailey, Mr. H. N. Sporborg, and Mr. P. S. Turner have been appointed Vice-chairmen of the Associated Electrical Industries Ltd. Sir George E. Bailey has been elected chairman of Metropolitan-Vickers Electrical Co. Ltd.; Mr. H. N. Sporborg has been elected chairman of the British Thomson-Houston Co. Ltd.; Mr. P. S. Turner has been elected chairman of the Edison Swan Electric Co. Ltd., Edison Swan Cables Ltd., and Ferguson Pailin Ltd.

Capt. L. H. Barton has been appointed Sales Manager, and **Mr. H. W. Horsman, A.M.I.P.E.,** outside representative for London and the Home Counties, of Messrs. Pitter Gauge & Precision Tool Co. Ltd., 49, Kingston Road, Leatherhead.

Mr. J. L. P. Brodie, M.I.A.E., and **Mr. Hugh Buckingham** have been elected directors of De Havilland Aircraft Co. Ltd.

Mr. J. W. Davies, director and general works manager of Messrs. Ferranti Ltd., Hollinwood, has been elected President of the Manchester District Engineering Employers' Association.

Mr. P. J. Dixon has been appointed General Works Manager to Thos. C. Fawcett Ltd., Leeds.

Mr. Charles S. Gill, director and general manager of Messrs. Davy and United Roll Foundry Ltd., has been elected director of Messrs. Davy and United Engineering Co. Ltd.

Mr. W. H. Glaser, M.A. (Cantab.), A.M.I.E.E., chief research engineer of Messrs. C. A. V. Ltd., has died recently.

Mr. J. Hill has been appointed technical and works director of the Vaughan Crane Co. Ltd.

Mr. D. Jackson and Mr. G. Keith Talbot have been elected directors of Messrs. Mavor & Coulson Ltd.

Mr. F. C. Mannox has been appointed managing director of Messrs. Murex Ltd. Mr. H. C. Green has become general manager of the company.

Capt. A. R. S. Nutting and **Air Commodore H. Peake** have been elected directors of the Westinghouse Brake and Signal Co. Ltd.

Sir William Palmer, K.B.E., C.B., has taken up the post of Principal Industrial Adviser to the Board of Trade. In this new post he will be specially concerned with major questions of industrial reconstruction policy in connection with the engineering and other industries at present mainly engaged on war production.

Dr. Harry R. Ricardo, F.R.S., the well-known consulting engineer, research worker and inventor who is responsible for a great many developments of the Internal Combustion Engine, has been elected President of the Institution of Mechanical Engineers for the year 1944-1945. An autobiography of Dr. Ricardo who is Honorary Member of the A.S.M.E., appeared in the November, 1943, issue of Mechanical Engineering, the official journal of the American Society of Mechanical Engineers.

Sir Oliver Simmonds, M.P., has been re-elected chairman, and **Capt. A. G. Lamplugh and Capt. B. H. Peter, C.B.E.,** have been re-elected deputy chairmen of the Joint Air Transport Committee, formed early in 1943 to consider post-war development of British civil aviation.

Mr. W. H. Smith has been appointed deputy managing director of Messrs. Allied Ironfounders Ltd.

Sir William Stanier, M.I.Mech.E., M.I.Loco.E., Chief Mechanical Engineer of the London Midland and Scottish Railway, who is now Scientific Adviser to the Minister of Production, has been elected a Fellow of the Royal Society.

Dr. C. Sykes, F.R.S., Superintendent of Metallurgy of the National Physical Laboratory and of the Terminal Ballistics branch of the Armament Research Department, has been appointed Director of the Firth-Brown Research Laboratories and technical adviser to the Firth-Brown group of companies.

Mr. Richard Wake, A.M.I.Mech.E., has been appointed Sales Manager of Messrs. John Ackworthie Ltd., Maypole Lane, Birmingham, 14. Previous to this appointment Mr. Wake was Assistant Director to the M.O.S. Department, Director General of Equipment and Supplies.

NEW EQUIPMENT.

P.V.E. STICK MICROMETER.

MODERN developments have created a demand for instruments suitable for gauging and making accurate measurements over distances of several feet, particularly in connection with the manufacture of aircraft, tanks and vehicles, and also in the jigs and fixtures used in their construction to ensure inter-changeability.

Pitter Gauge & Precision Tool Co. Ltd., Kingston Road, Leatherhead, Surrey, with long experience in making their well-known Standard Reference and Combination Length Bars and Slip Gauges, investigated the many problems involved in satisfying the demand and, as a result, have produced a Patented "Stick Micrometer," of robust construction and embodying several novel features.

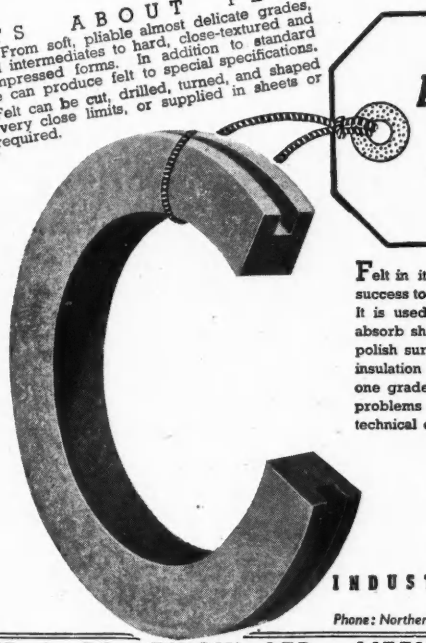
As seen from the illustration it consists of a micrometer head reading in .001 in. increments, a one-inch spherical end piece, and a number of intermediate distance pieces. These distance pieces are made in one-inch, two-inch, three-inch, five-inch, twelve-inch, and as many twenty-four inch lengths as are required to make up the desired total length.

The micrometer head, distance pieces and end piece are connected to each other by means of a self-aligning swivel screw at one end of a piece and a tapped hole in the end of the adjacent piece.

FACTS ABOUT FELT

Qualities: From soft, pliable almost delicate grades, through all intermediates to hard, close-textured and highly compressed forms. In addition to standard grades we can produce felt to special specifications.

Shapes: Felt can be cut, drilled, turned, and shaped to within very close limits, or supplied in sheets or strips as required.



ANOTHER PROBLEM SOLVED BY FELT

Felt in its many forms has already been applied with conspicuous success to literally hundreds of purposes, too numerous to detail here. It is used, to deaden sound, damp out vibration, prevent rattle, absorb shock, retain or distribute oil and grease, to seal joints, to polish surfaces, to filter liquids, to exclude draughts and for many insulation jobs. This should give you more than a hint that felt of one grade or another might well be the solution to many production problems which you have to solve. If you think so then our technical co-operation is at your service.

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Phone: Northern 2194-5 Grams: Felting, Birmingham

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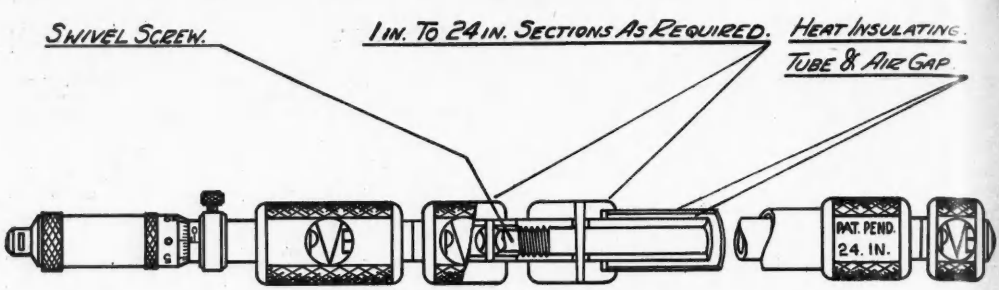

The P. V. E. Patented Stick Micrometer.

Each distance piece consists of an inner steel tube hardened at each end and accurately lapped to length, and enclosed by an insulating tube freely supported at the ends by ferrules of similar insulating material in such a manner that an air gap exists between the two tubes.

The insulating tube is allowed end movement, and is free to turn in the ferrule supports to avoid biassing the steel tube in any way. It also ensures the screwing together of the pieces through the medium of the ferrules, acts as an insulator and protector of the steel tube, whilst the patent swivelling screws ensure that the end faces of the pieces contact each other squarely.

An accuracy of $+.0002$ in. is maintained for the 12 and 24 in. $-.0000$ in.

pieces, and $+.0001$ in. for the others. A setting piece is provided $-.0000$ in.

to check the accuracy of the micrometer head and spherical end. Thus, in a 20 ft. length an accuracy of $+.002$ in. may be main- $-.000$ in.

tained. The reason for the tolerance being plus only is to allow for initial wear.

The "P.V.E. Stick Micrometer" is supplied in a neat case and many are now in use in factories and Government establishments where they are proving entirely satisfactory.

When long lengths of Stick Micrometer are used it is necessary to provide adjustable stands, Vee-blocks, or other form of support, to prevent deflection.

PLASTIC "CONFRACTOR."

Messrs. W. J. Steele & Co. Ltd., 641, Staines Road, Bedfont, Middx., have introduced a rapid calculation equipment for conversion inches to millimeter and vica-versa. The "Confractor" comprises three plastic discs which are fastened together in the centre with a brass eyelet so that they rotate upon each other. A slot is arranged on the left hand side of each outer disc, to reveal the figures printed upon each side of the middle disc and conversion is obtained by simply rotating the disc. The conversion data is covering the range from 11/128 in. to 6.15/16 inches and one to one hundred millimetres. The confractor can be used also for accurate calculations, as some of the conversions are made to seven decimal places.

BUTCHER-BLACK & DECKER EARTH PROTECTION.

The Butcher-Black & Decker Earth Protection unit is now produced on a commercial basis and marketed by Electro Methods Ltd. The scheme is claimed to provide full protection against shocks even in the event of failure of the trip coil. Leaflets describing some of the features of the scheme can be obtained by application to Electro Methods Ltd., 112, Brent Street, London, N.W.4.

B.K. MICROFILM CAMERA.

Messrs. Wray Ltd., Bromley, Kent, are introducing their new B.K. Microfilm Camera. The camera has been designed for making permanent records of documents, etc., and can be operated by an unskilled operator. Copy up to the size of foolscap can be accommodated and photographed. The ratio of size of copy to size of image is approximately 8 times linear. The distance from lens to copy being constant, there is no need to focus. The overall dimensions of the equipment are: height 36 inches; base 27×15 inches.

EASYSET TEE SQUARE.

We have received a circular from **Messrs. Taylor Brothers,** Castleton, nr. Manchester, describing their latest product the "Easyset Tee Square." The butt of the tee square is held against the straight edge of the drawing board by means of a spring loaded lever, which has an anti-friction roller working against a specially arranged guide. This guide is carried over the edge of the drawing board and provides a first class metallic straight edge which cannot be distorted. It is claimed that the knurled finger roller gives final setting with a great degree of accuracy.

BOOKS RECEIVED.

The Principles of Electrodeposition. By Samuel Field, A.R.C.Sc. Published by Sir Isaac Pitman & Sons Ltd., Parker St., Kingsway, London, W.C.2. 314 pp. $8\frac{1}{2} \times 5\frac{1}{2}$ in. Price 25s net.

In recent years the subject of electrodeposition, particularly with regard to the deposition of metals, has made enormous strides: the need for some simple treatment of the principles involved has been adequately met by the present volume.

This book, which may be regarded as the theoretical companion of *Electroplating*, deals with qualitative and quantitative electrolysis, the properties of gases and solutions, electrolytic conductance and dissociation. The many other branches of physical chemistry relating to the mutual transformations of chemical and electrical energy are also dealt with.

Whilst avoiding the mathematical treatment generally called for by the requirements of the more academic student, the book gives a fund of useful data in the form of tables and formulae, is well illustrated, and is one we commend to those concerned with the numerous and varied processes of electrodeposition.

The Works Engineer. By W. R J. Griffiths, M.Inst.F., A.M.S.W.I.E. Published by Sir Isaac Pitman & Sons Ltd., Parker St., Kingsway, London, W.C.2. 364 pp. $8\frac{1}{2} \times 5\frac{1}{2}$ in. Price 21s net.

This well-known manual on building and plant maintenance for the works engineer now reaches its second edition.

The work comprises twelve chapters dealing with office organisation and routine, steam, hydraulic, gas, air, electrical equipment, millwrighting, heating, buildings, transport, safety and fire-fighting equipment, each of which, in the author's words:—"would fill a book in itself."

Profusely illustrated, with diagrams, charts and log-sheets, the book is a condensed mass of information specially laid out for easy and rapid reference. A useful bibliography and index are included in this volume, which should prove of immense value to all whose job it is to keep the factories running efficiently.

Micromeritics. By J. M. Dallavalle, M.S., D.S. Published by Pitman Publishing Corporation, 2 West, 45th Street, New York, 19, N.Y. 428 pp. Price $8.50.

Micromeriiics is a new term introduced by the author for the science of small particles. The book covers in eighteen chapters all the aspects of particles ranging from 10^{-1} to 10^{3} micro ns, including the dynamics of small particles, shape and size distribution of particles, particle size measurement, sieving and grading, characteristics of packings, thermodynamics of particles, flaw of fluids through packings, determination of particle surface, theory of fine grinding, etc. Where it is essential the subject is treated mathematically, problems being given at the end of every chapter. It is an excellent text-book and reference book which should be of great value to students, teachers, and men in the practical field.

Aircraft Production, Planning and Control. By H. D MacKinnon, Jr. Published by Pitman Publishing Corporation, 2 West, 45th Street, New York, 19, N.Y. 254 pp. Price $3.75.

This book is concerned with methods and procedures that are found in every aircraft factory. It is written by no lesser authority than the production manager of the Beech Aircraft Corporation to inform those employed in manufacturing groups with the planning and controlling of aircraft production. In 250 pages, with clear drawings and good photographs valuable information is presented on the co-ordination between the shop and production department for those already employed in this line.

For those who may wish to enter the production department of the aircraft industry the book conveys a good idea of the essential features of organization as long as it is kept in mind that the subject cannot be taught from books alone. Experience and the knowledge of local conditions are all-important to ensure a smooth flow of fabricated parts to their final destination. Inasmuch as the book is written with an eye towards American conditions and methods the previous remark has a general bearing on the desirability of application of certain of its parts in this country. In spite of, or perhaps, for this reason, the book should be recommended with the speeding up of our vital war output.

Mathematics Dictionary. By Glenn James and Robert C. James. Published by The Digest Press, Van Nuys, California U.S.A. 320 pp.

An extremely useful reference book for students of mathematics and engineers in the practical field. It is a condensed source of facts and principles containing definitions of the basic nomenclature used in mathematics, mathematical formulae, and a large number of tables needed day by day in course of mathematical work.

Economical Lubrication of Steam Turbines and Reciprocating Steam Engines.

The Ministry of Fuel and Power is to be congratulated on the well and clearly written and neatly produced booklets designed to economize oil consumption. No. 3 of the Oils series, just published, gives on twenty pages a great amount of simple and useful advice on how great economies can be effected in the consumption of lubricating oil. Users of Steam Turbines and Reciprocating Steam Engines are, therefore, well advised to take advantage of this service by applying for copies to the Secretary of the Ministry of Fuel and Power (Coal Division), Dean Stanley St., London, S.W.1.